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Monthly Bulletin of the International Railway Congress Association

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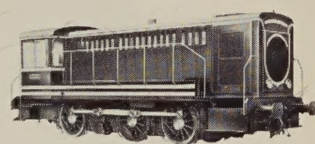

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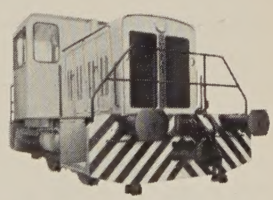

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MONTHLY BULLETIN

OF THE

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

(ENGLISH EDITION)

PUBLISHING and EDITORIAL OFFICES : 19, RUE DU BEAU-SITE, BRUSSELS

Yearly subscription for 1956 :

Belgium	. . . .	**700 Belgian Francs**
Universal Postal Union	. .	**800 Belgian Francs**

Price of this single copy : 80 Belgian Francs (not including postage).

Subscriptions and orders for single copies (January 1931 and later editions) to be addressed to the General Secretary, International Railway Congress Association, 19, rue du Beau-Site, Brussels (Belgium).

Orders for copies previous to January 1931 should be addressed to Messrs. Weissenbruch & Co. Ltd., Printers, 49, rue du Poinçon, Brussels.

Advertisements : All communications should be addressed to the Association, **19, rue du Beau-Site, Brussels.**

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Vol. XXXIII. — No. 11. November 1956.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[625 .285]

Results obtained as regards the sound proofing of railway vehicles with thermal engines,

by Otto TASCHINGER, Dipl.-Ing., Munich.

(*Eisenbahntechnische Rundschau*, March 1955 issue).

The comfort of travelling by rail.

Amongst the advantages of travelling by rail, the comfort enjoyed by passengers is in fact of the utmost importance. One essential condition of comfort is the feeling of security whilst the train is running. The standard of safety achieved as the result of a century of experience, the evolution of which has never been sacrificed to considerations of cost, means that even at high speeds a high standard of safety is assured which the passengers take for granted. The impression of comfort is further increased by the size of the compartments and the various installations with which railway vehicles are equipped. The same convenience cannot be even approached with other forms of transport, not even aircraft. In this connection, only ships can stand a comparison with railway vehicles.

The dimensions of the compartments, their heating and ventilation, the comfortable seats, which are being increasingly upholstered to a very high standard even in third class, the good lighting at night, the possibility of reading and writing, the great freedom of movement in the compartments and throughout the whole train or rake, the possibility of having a meal or reserving a sleeping berth, the installation of toilets and washing facilities, all these facilities, as well as many other conveniences assure a high standard of comfort for passengers, even in the case of long journeys.

Comfort can however be reduced when the train is running by two disturbing influences. The first is the movement which may be due to the running gear of the coaches, the state of maintenance of the rolling stock or the track; suitable constructional methods and very careful maintenance makes it possible to avoid this, and this has in fact been done very successfully on a large scale.

The second disturbing factor consists of noise in the vehicle itself; in this article, we propose to study the possible ways of reducing this, starting with the actual design of the vehicles. At the same time, we will make known the practical results obtained by the Deutsche Bundesbahn in the fight against noise in the case of vehicles with thermal engines built in recent years.

Vehicle noises.

The fight against the noise made by railway vehicles is of great importance because the noises are not only emitted in the neighbourhood of the vehicles

(*outside noises*) but also because the noise in the interior of the vehicles (*inside noises*) is extremely disturbing. There is no doubt but that passengers much prefer the less noisy vehicles. Sound-proofing vehicles is therefore of great value from the publicity point of view. It is a particular problem which must not be neglected in the general struggle against traffic noises.

The amount of noise in railway vehicles is considerable. The outside noise of a vehicle may amount to 126 phons or more, i.e. it is very close to the intensity at which noise actually becomes painful. The noises produced are a mixture of various frequencies the most important of which vary from 50 to 3 000 Hz.

The effects of noise upon the human ear are a psycho-physical problem. The sensitiveness of the human ear depends a great deal upon the frequency of the noise. Sounds which are equally loud have much less effect when they are of low frequency than when they are of high frequency. The effect of constant loud noise may be to induce excessive fatigue, insomnia, nervous depression, irritability, vertigo, and stomach and heart disorders. Constant loud noise may even lead to permanent deafness. Experiencing any of the above effects and the results thereof during a railway journey depends amongst other things on the physical constitution of the individual, the length of the journey, and the running and noisiness of the train.

The locomotive and railcar crews and the train staff have to work with concentration during the journey, which means sustained attention often for long periods at a time and consequently much concentration of their intellectual powers. Excessive noise in the vehicles means they are subjected to additional physical fatigue, which moreover it is not possible to reduce by using any way of stopping up their ears, as this might prevent them from receiving the acoustic signals. Sufficient protection against the noise in the vehicles can only be obtained by sound insulation of the driving and service compartments in the vehicles themselves.

Outside noises.

Outside noises during running are definitely louder in the immediate vicinity of the vehicles than the inside noises. It is a known fact however that the intensity of noise decreases very rapidly with the distance. They are therefore of special importance when they affect persons in the immediate vicinity. In this case a distinction must be made between the outside noises of vehicles running on the open line, on leaving and entering stations, and also whilst they are stopped. On the line, where the trains run past at speed, the houses are sufficiently far away from the line for the outside noises of the trains not to be serious, especially as they only come at long intervals and do not take long to pass. It is the same in the case of the noises on entering and leaving stations, the latter being moreover less noisy as the speeds are lower.

Outside noises in the stations made by vehicles with thermal engines are mainly due to the Diesel traction motors running light, to the air compressors and other motors. Unless protective measures are taken on the vehicles, the noise made by the engines is so great that it may be hard for the train staff and locomotive or railcar drivers to hear the acoustic signals and the instructions given by officials. In addition, these outside noises are very annoying to passengers standing on the platforms. Outside noises must not be overlooked when trying to reduce the noise made by vehicles.

Inside noises.

The fight against inside noises also depends to a large extent on the source of the noise inside the vehicles. Three groups of vehicles have to be taken into account : locomotives, railcars and

coaches, including the driving vehicles and middle coaches of multiple units and the trailers of railcars.

In the case of locomotives with thermal engines in addition to the actual running noises, there is also the noise of the motor units (Diesel motors), of the air compressors, of the fans and their motors, as well as the other motors needed for the auxiliary equipment. The noises of all these motor units may exceed the actual running noises. Protective measures against noise on locomotives should be so devised that the noise in the driving compartments is about the same as that in the passenger compartments. When the side windows of the driving compartment are open, the acoustic signals and instructions given by officials must be easily heard. The amount of noise in the machinery compartments must be sufficiently reduced for the locomotive staff not to suffer when they have to remain therein at times.

In railcars, the passenger compartments are usually separated from the driving compartment and machinery compartment by the luggage or mail compartment or the entry vestibules, and are not accessible to passengers or only used by them momentarily.

From the acoustic point of view, the driving compartment and the machinery compartment of railcars should be treated in the same way as on locomotives, but here there is additional difficulty due to the fact that the motor groups of railcars mounted on the bogies penetrate into the body through large openings in the floor. In any case, properly insulated partitions must be fitted between the engine room on the one hand and the driving compartment on the other as well as the luggage and other adjoining compartments. The passenger compartments on railcars are generally sufficiently far removed from the engine room for the protective measures used in the case of passenger coaches to be sufficient.

The interior compartments of passenger coaches only need to be insulated against the actual running noises.

Running noises in the coaches depend on the speed. Between 30 and 90 km (18 and 54 miles)/h the inside noise of the coach increases by about 2 phons for every 10 km (6 miles)/h increase in the speed. From 90 to 120 km (54 to 72 miles)/h, the increase in the noise becomes smaller and smaller, and above 120 km/h, there is no perceptible increase. The noises made by the vehicle itself on the other hand depend upon its design, on the track, on the state of the running surface of the rails and the environment of the train, varying according to whether it is running in the open, in a cutting, over a bridge or through tunnels. In the old types of compartments without sound insulation, especially on metal coaches — and amongst these latter more particularly in the case of the light weight coaches — the inside noises amount to 110 phons and over. These noises are very trying for the passengers, particularly because of the powerful effect of the high frequency portion; it is only possible to converse by raising the voice very high.

Sources of noise.

To combat noise in railway vehicles is a very difficult matter as the noises come from so many different sources. The wheel as it runs is the generator of the greatest amount of noise. Any unevenness in the tyres and the running surface of the rails as well as longitudinal and transversal friction of the wheel against the rail set up vibrations in the tyres and the wheels themselves which give rise to loud noises of various frequencies.

In passenger coaches, the noise from the axle exceeds by far in intensity all the other noises produced in the vehicle. Besides these noises, there are bangs from the mobile parts of the vehicle, the noise of the wind set up during running by

protruding parts of the vehicle or the body, and finally the noise of the friction between the wheel and the brake shoe when the train is braked, or between badly fitting partitions.

In traction vehicles with thermal engines, there are further sources of noise : the Diesel engines with their exhaust noises, the radiator fans and their motors, the generators and electric motors for starting, lighting and heating, as well as the air compressors for the brake equipment, etc. The noise made by internal combustion engines is considerable; it depends upon the number, power and speed of rotation of the Diesel motors fitted. The frequencies for the starting up of the Diesel engines lie in the lower zone of the frequencies for speech. The low frequencies affect the human ear less than higher frequencies of the same value, but technically it is harder to eliminate them. Whereas running noises, which include a great proportion of high frequencies, can be effectively damped out, the low frequencies still remain audible, usually in the form of a booming noise.

Noise can be propagated *in the air* around the point at which it is caused, or, since it is due to vibrations, can be transmitted as *sonorous vibrations* by those parts of the bogie and body which can vibrate; the thin outer sheeting in particular easily vibrates and in turn radiates sonorous vibrations in the inside of the compartments through the air. The outside noise propagated in the air can also give rise to sonorous vibrations in the sheeting covering the body of the vehicle.

To be successful in soundproofing, this must include everything that generates noise. For example if special measures successfully got rid of the part of the noise corresponding to a certain sonorous frequency, the effect on the total noise would be very little because this consists of the sum total of the logarithmes of the different noises of all frequencies.

Influence of the track on running noises.

Running noises are caused by the running of the wheels on the rails. The track, consisting of the rails, the sleepers and the ballast, plays an essential part in causing noise. Running noises are transmitted by the rails and radiated throughout their neighbourhood in the form of vibrations in the air. Studies of the part played by the track in running noises have already made it possible to collect some important data. They have shown that the different rail profiles, types of ballast and variations in the subsoil have no effect; on the other hand, the noise is different according to the type of sleeper used (wood, metal or reinforced concrete).

The possibilities of the influences, which we have just mentioned, are greatly exceeded by the formation of noise at the rail joints and at the track appliances. It is however the condition of the surface of the rails over which the wheels run that has the greatest influence on the running noises. This is clearly apparent when comparing rails showing undulatory wear and those without such wear (1).

When the wheels run over the joint gaps *shock noises* are produced; when they run over rails with undulatory wear very loud *howling noises* are produced.

The intensity of the shock noises at the joints depends upon the condition of the joints (length of the gap and relative level of the rail ends; on the axle load and the arrangement of the running gear (single axle or two axles, type of bogie). Such shock noises are avoided by laying jointless rails. In this way also there is an appreciable improvement in the quality of running, and a striking reduction in the running noises, as had already been

(1) We are taking it that the problem of undulatory wear is sufficiently well known by reason of the numerous publications which have been devoted to it.

generally noted on long sections of welded rails without joints on the Deutsche Bundesbahn.

The grating noise due to undulatory wear can exceed in intensity all the other running noises. The important sonorous frequencies of rails with undulatory wear lie in the scale from 50 to 900 Hz. During running, two groups of frequency due to undulatory wear can be clearly distinguished : 70 to 90 Hz and 300 to 900 Hz. As we will see later on, the frequencies of the wheels themselves also lie within these limits.

In figure 1, we have shown the influence of the various types of permanent way upon the formation of noise as a function of the speed for rails with and without undulatory wear. This shows that track laid on metal sleepers is worse from the point of view of setting up noises than track on wood or reinforced concrete sleepers. For example, the outside noise for track laid on metal sleepers is 117 phons at 50 km (31 miles)/h and 124 phons at 100 km (62 miles)/h; on track with wood sleepers this increase in the noise is usually less appreciable. The comparative figures show particularly clearly the greater noise produced with rails having undulatory wear.

Type of vehicle and the formation of noise.

The noises in railway vehicles depend to a large extent upon the design of the vehicle. They are affected by :

1) the outer form of the vehicle, especially its body;

2) the materials of which the body and running gear are made;

3) the dimensions of the different components of which the vehicle is constructed;

4) the way the different parts are joined together and the pivoting of the mobile parts;

5) the intercommunication arrangements between vehicles;

6) the axles and suspension of the running gear.

1. — *Influence of the shape of the vehicle.*

In order to avoid wind noise, the outside of the body of the vehicle must be so shaped that the surrounding air is

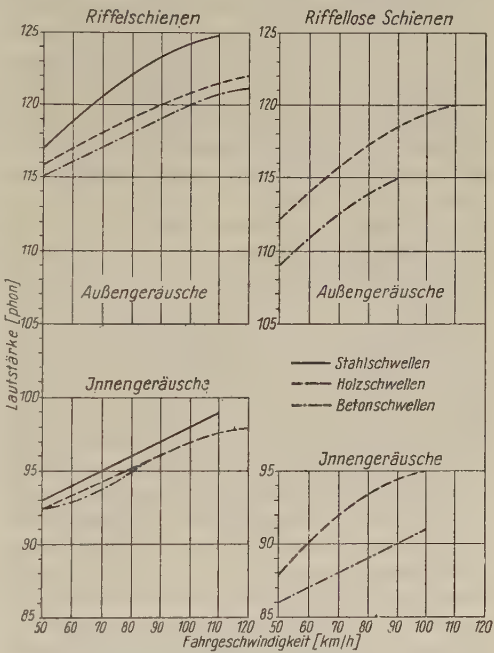

Fig. 1. — The formation of noise with different types of track.

N. B. — Lautstärke = intensity of noise (phons). — Fahrgeschwindigkeit = speed of running. — Riffelschienen = rails with undulatory wear. — Riffellose Schienen = rails without undulatory wear. — Aussengeräusche = exterior noises. — Innengeräusche = interior noises. — Stahlschewellen = metal sleepers. — Holzschwellen = wooden sleepers. — Betonschwellen = concrete sleepers.

passed through with the minimum of resistance and no eddies are produced during running. This is the reason why the ends of express vehicles have been streamlined. In addition, all the outside of the body, in other words the front,

sides and roof and the outside surface of the body must be smooth, i.e. with no jutting-out angles, protusions or other constructional details. This condition is met by making the windows and entry doors flush with the outside of the walls. It is also advantageous to cover in with smooth sheeting all the equipment, engines, brake gear, heating equipment, etc., fitted under the floor of the coach. This is done by extending the sides downwards by means of petticoats, joining them together by a lower sheeting and covering in the ends of the false-floor with sheeting.

Streamlining the running gear, for example the bogies, presents some special difficulties. Obviously, it is possible to cover a bogie with a hood, bringing it round the front, back and two sides, streamlining it from top to bottom, only leaving the wheels at the bottom and pivot at the top uncovered. If thoroughly sound-proofed, such a hood will aid in reducing noise. This is particularly necessary seeing that it is at the axles that the noises start and have the maximum intensity. But streamlining also causes various inconveniences. Bogie axles, together with the axle boxes and the suspension gear, the brake gear, and in the case of motor bogies, the driving gear, require maintenance in service and consequently must be readily accessible; any sort of hood makes them much less accessible, although still possible if shutters that can be hermetically sealed are provided.

In addition the sheet hood prevents and impedes the dissipation of the heat given off when braking, unless special aspiration devices are provided. The streamlining of the bogie can only be taken down as far as the bottom of the vehicle gauge, so that the wheels remain outside it; here air vibrations can easily be set up. Trials made to prevent the propagation of the noise made by the bogie in the form of air vibrations by means of a temporary streamlining formed by an insulated sheet hood have been carried out on one coach; they were not successful. This result was mainly due to the small proportion of noise due to air vibration in the total noise set up the vehicle and the fact that it was impossible to carry the protective sheathing down as far as the track.

2. — *Influence of the constructional materials.*

The noise made by the wheels is transmitted to the body through the bearings, suspension springs, the bogie and the frame. In electrotechnique the electric resistance of a given material is measured in ohms. Each material has also an acoustic resistance the unit of which is the « acoustic ohm ». But whereas in electrotechnique endeavours are made to find materials with as low an electric resistance as possible, in the case of the acoustics of construction, the best materials are those which have as high an acoustic resistance as possible. Table I shows the acoustic resistances of the most important materials used in the construction of vehicles with their density and their sound transmision speeds.

The acoustic resistance of a material is a function of the specific weight and sound transmission speed of this material. As the specific weight increases, the acoustic resistance also increases. Any advantage from the acoustic point of view can therefore only be obtained at the cost of increasing the weight. One of the most important materials used in the construction of vehicles is steel which has a very great acoustic resistance.

3. — *Influence of the dimensions of constructional components.*

Sensitivity to noise is further increased when the human organism is exposed to mechanical vibration at the same time as to the influence of noise. The passenger seated in a coach will get the impression that the running noises are

TABLE I. — **Density, sound speed and acoustic resistance of various materials used in the construction of vehicles.**

Material	Density ρ g/cm³	Sound speed c (longitudinally) m/sec.	Acoustic resistance $z = \rho \cdot c$ Ω acoustic $\frac{\text{dyn. sec.}}{\text{cm}^3}$
Air at 20° C, 760 mm Hg. . . .		343	41.3
Cork	0.2	500	10 000
Oak	0.75	(following the grain) 3 300	250 000
Rubber	0.9 to 1.5	35 to 120	3 150 to 18 000
Sand	1.4 to 1.8	100 to 1 800	14 000 to 324 000
Glass	2.5	5 500	1 380 000
Aluminium	2.7	5 100	1 370 000
Steel	7.8	4 900	3 820 000
Brass	8.3	3 500	2 910 000
Lead	11.3	1 300	1 470 000

much greater if he is constantly subjected to any considerable vibration, vertical or horizontal, vibrations of high frequency being more noticeable than those of low frequency in a swaying movement, even if the latter are greater. Inversely, defects in the running of a coach appear worse when there is a loud noise in the passenger compartment. There is therefore a relationship between running noises and mechanical movements of the vehicle which must not be overlooked.

As a result of unevenness in the track, whilst running, the body of a vehicle is subjected to vibrations of variable intensity and frequency. The value of these vibrations is a function of the condition of the track, especially the running surface of the rails, the rail joints and the gauge, but to a large extent the design of the running gear of the vehicle (axles, axle bearings, suspension, type of bogie) and finally, of the degree of rigidity and method of support of the body on the bogies. Transversal shocks acting on the body must be damped out, and in such a way that these can oscillate transversally after being damped out at as low a frequency as possible. The bogie and body must be so proportioned in relation to each other that no resonance is set up. When designing the body and its internal arrangement, care must be taken that not only the body as a whole but also the different components do not vibrate (for example, vibration of the floor or walls, etc.).

4. — *Influence of the connections and pivoting of mobile components.*

Vertical and horizontal vibrations of the body of the coach are generally caused by elastic deformation. During this deformation, rubbing may occur between various components, for example where the sides and partitions are joined together, and this results in creaking noises. To avoid such noises, all constructional details should be solidly connected together. It is a good plan to fit bands of felt at the joints in wooden partitions. Creaking or grinding noises occur when the pivoting or sliding points of the rods or other movable parts are not adjusted with precision and consequently there is a gap. All

bearings and guides should be so adjusted that there is no play, and maintained without play. There must also be no play in the window frames; to avoid rattling, it is a good plan to line them with bands of felt or plush.

5. — *Influence of the intercommunication arrangements between vehicles.*

Usually, the connection between coaches is closed in by bellows, bands of rubber or rubber flanges. Such intercommunication devices which usually have very thin walls are not air tight. The exterior noises around the ends of the coaches, which are at their maximum at these points owing to being in the immediate vicinity of two adjoining bogies, can penetrate into the coach without any hindrance. In certain cases, the inside bellows is duplicated by an outside bellows so that the two ends of the two coaches are enclosed in an airtight sheath. This second casing, however, because of the thinness of the rubber or the bellows does not lead to any appreciable reduction in the noise, unless other sound insulation measures are also included. Technically it is not a simple matter to make the bellows soundproof, and this also involves additional cost and weight. The most effective protection against the penetration of noise into the coaches is to fit doors at the ends which close hermetically. Such doors have however to be so designed that they only open when a passenger wishes to pass through and close automatically afterwards.

6. — *Influence of the wheels and axles and running gear.*

The wheel and axle set is one of the most important sources of noise and one of the essential tasks in the fight against noise is to design such a set as will prevent such noise being produced or which only cause noises of low intensity. In spite of important trials and many patents, this problem has not been entirely satisfactorily solved to date. The use of pneumatic tyres instead of steel tyres which has been tried abroad on fast long distance trains has not given the expected results, owing to the heavy axle loads, the narrowness of the running surfaces and the long distances run non-stop. The axles with rubber suspension which the Deutsche Bundesbahn is now trying out on various vehicles has not yet been proved completely satisfactory. With rubber suspension a reduction of about 3 to 7 phons has been measured on the wheels, but no improvement in the suspension of the vehicles has been noted with such axles. Another point that remains to be cleared up is the ageing of the rubber, which is encouraged by the heating up due to running very long distances non-stop. This may affect the life of the rubber as when it ages it hardens. The set of wheels with rubber suspension has moreover the drawback of having a greater running resistance than the normal coupled axle. A comparison with the tramways on which such axles with rubber suspension have given good results in the fight against noise is not possible owing to the short distances between stops and the smaller axle loads which are the rule with such vehicles. For some time, noise in the wheels themselves has been damped out by means of absorbant material which are sprayed on, the thickness of such « sound-deadening » materials having to exceed 1 cm (3/8″); suitable treatment of the discs of the wheels has led to a reduction in noise of about 4 phons. Here again, some time must elapse before final judgment can be passed on the way it wears and in particular on the useful life of such coverings. The vibrations transmitted from the wheel and axle set to the bogie frame and thence to the body of the coach can be absorbed by inserting rubber blocks. In this case, the frequency of these rubber blocks must be as much as possible below the frequency of excitation. If for constructional reasons, this is not possible and the frequencies are very close to each other, there will be a slight reduction in the noise, but the

mechanical vibrations will not be damped out.

As to date it has not been possible to eliminate vehicle noises by constructional measures in connection with the wheel and axle set and the rail, nor to confine them sufficiently at these points, the only thing to be done is to prevent them penetrating into the interior of the coach as much as possible.

The production of noise by the motor installations.

In units with thermic motors the noises generated by the motor equipment are added to those due to the method of construction. We have already gone into this in detail, both in the chapter devoted to internal noises and outside noises and that dealing with the sources of noise. Amongst these, the most important are the Diesel engines with the exhaust noises, and the fans whose noise penetrates into the interior of the coach through the air ducts and which may cause a rumbling in the sheet walls of these ducts.

In the fight against these noises, progress has been achieved by the use of relatively silent exhaust pots. The noise of the fans has been considerably reduced by the use of balanced compressors with practically silent suction and check valves. Radiator noises have been reduced by following certain aerodynamic rules in designing the air ducts (sufficiently large ducts, doing away with restricted section, using curves of large radius), the sheets guiding the direction of the air flow and the blades of the fan, as well as by using cast iron blades for the fans, etc.

The method of mounting the various motors on the bogie frame or the body has a very great effect on the amount of noise made by the engines and eliminating vibrations. Mounting such motors on supports with rubber in shear has resulted in substantial advantages.

In addition, the methods used to sound-proof the motor installations still require perfecting and involve additional constructional costs.

Methods of fighting noise.

The problem of noise is dealt with in building construction under the general heading of « *building acoustics* ». In view of the considerable importance of the fight against the running noise, the enormous number of vehicles of all kinds in service. and especially on account of the extraordinary multiplicity of the types of noise due to the construction of the vehicles, as well as the possibility of fighting such noises, it appears opportune to introduce into the technique the idea of « *vehicle acoustics* ». Under this general heading may be included such problems for all types of vehicles : railway vehicles, road motor vehicles, boats and airplanes, because in most cases the causes of the noise are similar and the same methods of fighting it can be used. Under the heading « vehicle acoustics » we can also deal with the noises of the medium in which they circulate (for example the permanent way in the case of railways, bridges, etc.) and its environment (for example, tunnels, cuttings, narrow streets, etc.).

Amongst the most important methods of fighting noise, mention must be made of constructional materials whose nature is such that they reduce the noise, which later on will be referred to as *anti-noise materials*. In the construction of vehicles, the sole task of these materials is to prevent as far as possible the formation or propagation of noise; they cannot be used for other purposes, for example as stress-bearing components of the body; consequently their use means that the weight is increased.

In the body, it is possible to introduce such anti-noise materials in the floor, in the side and end walls, and in the roof. When used in these places their thickness is naturally limited : in the case of the floor because of the height of the side

sills and cross members, in the case of the side and end walls by the space between the outer sheeting and the inside casing which is generally made of plywood sheets. In the roof there is the greatest amount of space available between the outside roof and the ceiling, but in certain cases this also is reduced by the presence of the hot or fresh air ducts. It is on the front and side walls in view of the small distance (50 to 70 mm [2″ to 2 3/4″] only as a general rule) between the inner and outer walls that the possibility of sound proofing is the most restricted. The many large windows (together with the space for the sliding frame in the older vehicles) and the doors (as well as the corresponding openings in the case of sliding doors) considerably reduce the effectiveness of sound insulation unless silent double windows and particularly well fitting doors that are both air tight and noise tight are fitted.

In the case of motor vehicles, the fight against noise is made still more difficult by the large spaces left in the floor to give room for the parts of the motor group fitted on the bogie which project into the body, as well as the other openings in the floor and in the roof for the outlets of the ventilators and the radiators of the Diesel engines.

In view of the small amount of room available in the body of the vehicles, on the one hand, and the amount of noise produced by the different sources, on the other, it is not sufficient to fill in the empty spaces in the construction of the vehicle with materials having great sound-proofing qualities. The increase in the weight would be much too great. To combat the noises resulting from the vibration of the air and the vibration of the solid parts, we have to make use of insulation, damping out and the absorption of noise, and take care in chosing the measures to be taken that whatever will increase the weight will remain within moderate limits.

The human ear answers to an extraordinary extensive scale of sound waves, from 10^{-16} W/cm² (the opening range) to 10^{-3} W/cm² (limit of pain). In view of this vast range of 10 trillion watts, sound values can only be conveniently given by using a logarithmic scale. The unit of measurement used for this purpose, the *decibel* (dB), is a logarithmic ratio of the intensity considered at the opening range. For example, in this way it is possible to express the ratio between pressures, energies and powers of sound, taking into account in a uniform fashion all the frequencies of a noise. The human ear, however, differentiates an incidental noise when the frequency is varied. For this reason, besides the decibel, there is another system of measurement, the *phon,* which takes into account sensitivity of the ear to the frequency. At a frequency of 1 000 Hz, the phon and the decibel coincide.

Insulation.

The name of sound insulation in the construction of vehicle is reserved for materials which are placed in empty spaces and have as great as possible an acoustic resistance to the passage of noise. The constructional materials actually speaking used in the body and the interior fittings are not insulators although, as we said above, such materials may have some degree of acoustic resistance. The acoustic insulation coefficient of a material is measured in decibels.

Glass wool, Iporka, synthetic rubber foam, slag wool, cork, cork waste, pieces of felt, asbestos, or rubber products can all be used as insulators. In the new railcars and Diesel locomotives of the Deutsche Bundesbahn, sheets of glass wool, ribbons of glass fibre or Iporka are generally used; their insulating coefficients are given in Table II.

Some of these insulating materials, as we shall see further on, are also used as damping out or absorbing materials. The insulator cannot be considered by itself, its sound-proofing effect is only produced when it is fitted correctly in the vehicle.

TABLE II. — **Insulating effect of different materials.**

Insulating material	Improvement compared with empty space in dB				
	128 to 256 Hz	256 to 512 Hz	512 to 1 024 Hz	1 024 to 2 048 Hz	2 048 to 4 096 Hz
Iporka in thin sheets in a container 10 kg/m³	4	4	6	5	5
Glass wool mattress, 46 kg/m³	4	13	8	6	7
Ribbons of glass wool in muslin cloth 80 kg/m³ (marginal insulation). . .	2	8	8	4	7

Only materials whose insulating coefficients are guaranteed by the official testing services should be used as insulators. Such products should not have a lower density than that prescribed, should not be structurally modified by the dynamic stresses which occur in service, should not absorb or retain water or other liquids, nor corrode wood, metal or any other material used in the construction of the vehicle. They must have no smell, must not rot, must not be attractive to germs or vermin, and must be uninflammable.

Damping out.

In modern railway vehicle bodies, for the outer covering, the partitions and other walls (heating and air ducts) steel or light metal sheeting is used, generally 1 to 2 mm (3/64″ to 5/64″) thick. Such sheeting is rivetted or welded to a framework consisting of a series of different sized openings also made up of folded sheets or thin sections; these are subjected to vibration during running owing to unevenness in the track or in the motors fitted to the vehicles. Vibrations in thin sheets produce noises of a frequency of 50 to 1 000 Hz, which have their repercussions inside the vehicle or outside through vibrations in the air; the sheets « rumble ».

If such sheets are made to vibrate themselves, the vibrating energy is destroyed at length by calorific losses inside the vibrating system, by the transmission of vibratory energy to adjoining portions of the vehicle to which they are rigidly fastened, and by the radiation of the sound through the surrounding atmosphere. The slower the destruction of this energy, the longer the period during which energy is available to set up vibrations in the air, in other words, the longer the period of resonance. The value of the destroyed portion of the total vibratory energy is known as the loss factor and designated by η. With the thin sheets used for vehicles, internal calorific losses are very small. Measurements have shown that the loss factor η of steel sheets of 1.25 mm thickness for example were only 0.0013 to 0.0014. As a comparison, wood has a loss factor thirteen times as great.

The stress oscillations of the various thin sheets of the body can be damped out and consequently the time of resonance reduced by the use of sound-proofing products stuck firmly to the sheets. Such products are intended to destroy the stress vibrations in such a way that the thin sheets can no longer produce noise in the same way as the membrane of a loud-speaker.

Sound-proofing materials, in addition, have a certain insulating property and

absorb noise. As they have a low calorific conductivity, their use also improves the thermal insulation of the vehicles.

So far asbestos or cork flock, glass whool products and synthetic resins (Antivibrine) have been used as sound-proofing materials in the construction of vehicles, Asbestos flock for example has a loss factor about 20 times as great as that of steel sheet, in other words is even better than wood.

During recent years, considerable progress has been made in the manufacture of sound-proofing materials. Such products are manufactured from natural and artificial polymers to which suitable additions are made. Some such additions possess a relatively low density and a high modulus of elasticity (2). The mixture of polymers and fillers must be so selected as to give the maximum damping out effect. With the correct amounts, it is also possible to obtain great rigidity in conjunction with a very low density. The damping out effect can be further increased by the association of several high polymers for the temperature values and frequency of vibration to be covered. In addition, the mixture can be made in such a way that the degree of damping out of the sheet is independent of the temperature and in such a way that the rubber will age comparatively little. The density of sound-proofing materials is from 0.5 to 0.6 g/cm³.

Amongst the additions, « vermiculite » plays a special part. This is a form of mica, obtained from mica waste which swells when it is heated to 1 200° C so that its specific weight falls to at least 1/10th.

(2) H. OBERST and G. W. BECKER : « Über die Dämpfung der Biegeschwingungen dünner Bleche durch fest haftende Beläge. » *Akustische Beihefte* 1954, No. 1.

Dr. A. STANKIEWICZ GmbH : « Entdröhnungsmittel Schallschluck. » Fabrik für Gummilösungen. Offenbach a. M. — Publicity leaflet.

The loss factor depends upon certain limits of thickness of the layer; on this in turn depends to a large extent the weight of the sound-proofing. The loss factor is a function in addition of the ratio between the mass of the layer and that of the sheet. In the case of the covering of vehicles, the ratio should be about 20 to 35 %. The loss

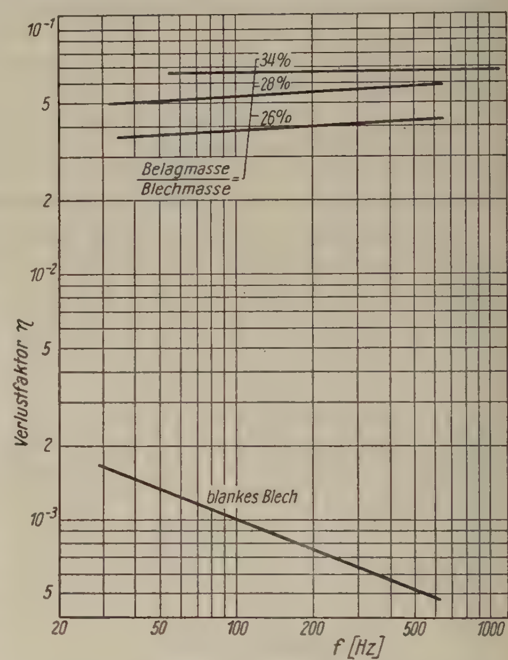

Fig. 2. — Relation between the loss factor of bare sheets and damped out sheets and the frequency.

N. B. — Verlustfaktor = loss factor. — Blankes Blech = bare sheet. — $\frac{\text{Belagmasse}}{\text{Blechmasse}} = \frac{\text{mass of the covering}}{\text{mass of the sheet}}$.

factor of good sound-proofing materials is practically independent of the effective vibration frequencies and temperatures. Figure 2 shows the variation as a function of the frequency of the loss factor η for sheets covered with sound-proofing layers of the « Fabrik für Gummilösungen » of Offenbach-on-Main compared with bare sheets.

There must be no special difficulty attached to covering treated or untreated sheets with the sound-proofing layer, even in a vertical position. It is recommended to cover the sheeting and its rigid framework by an undercoating. As a rule, the sound-proofing material is sprayed on; it should adhere to the sheets immediately it is sprayed and dry very quickly. In this connection, it is a good thing if sound-proofed sheets can be welded should they suffer any damage (after a train accident for example) without having to take special measures and without being troubled by fumes. After welding, the repaired sections must again be sprayed with sound-proofing material. The layer must be uninflammable, adhere solidly and lastingly, be stable at high temperatures, resist mechanical stresses and scratches, and be unaffected by oil and water repellant. It must not corrode the sheets and should at the same time protect them against corrosion.

It is not necessary for the material to be sprayed on in a uniform layer over the whole of the same wall. The thickness is a function of the sensitivity to vibration of the place in question. On the beam sections which stiffen the roof, as well as at all other centres of vibration and in their neighbourhood, the thickness may be as little as 1 mm, whilst on the framework of particularly thick walls there is no need for it at all. The most economic results are obtained with a thickness of 2 to 3 mm on sheets of 0.8 to 1 mm and 3 to 5 mm on sheets of 1.5 to 3 mm. The weight of the covering in the first case amounts to about 2 kg/m^2 in its liquid state and 1.5 kg/m^2 when it is completely dry. In the second case, the corresponding figures are 3 and 2 kg/m^2. In the case of aluminium sheets, it is the practice to count on using 1 to 1.5 kg/m^2 without bothering about the thickness of the sheet. With the sound-proofing materials in question, loss factors of 0.04 to 0.07 are obtained.

The sound-proofing layers completely mask the surface of the sheets. They must therefore only be put on sheets and profiles where it is absolutely certain there is no risk of any cracks. Experience has shown for example that light welded sections or sheets welded to form the bogie frames have a tendency to crack when the sections are too small or when the flux of power from one beam to another is interrupted. If it is not absolutely certain that the start of a crack in the beam will show at the same time at the same place on the covering, sound-proofing materials must not be used on these parts.

Absorption.

The passenger and service compartments of railway vehicles are usually made up of plywood partitions which are polished and painted, or in sheeting covered with a coat of lacquer or fabric. Dealing with the acoustics of these vehicles, such partitions are said to be *hard*. The noise inside the vehicle is reflected when it strikes against a hard partition, so that it sets up vibrations in the partition, which are the source of further noise. The noise due to the air vibrations which penetrate into the compartment can be lessened by covering the partitions and ceiling with absorbant materials or by selecting for the ceiling and wall coverings types of construction such that the noise can without difficulty pass through them.

Special materials for absorbing the noise produced by the air are called *absorbant materials*. They are soft and porous materials in which the air imprisoned in the pores is made to vibrate by the noise. The vibratory energy engendered in the pores is in part transformed into heat by the friction and as a result considerably reduced.

The aptitude of a material to absorb noise is measured by its *degree of sound absorption;* this is the percentage of sonorous power absorbed by the material

compared with the total sonorous power transmitted by the air. The degree of absorption of the noise depends to a large extent on the frequency and, to a greater or lesser extent, on the ambient temperature. In addition, the action of absorbing the noise depends also upon the thickness of the absorbing material and the constructional arrangement of the vehicle. According to Professor Lothar CREMER, the thickness of the absorbing material should be $d = \frac{100}{\rho}$, d being the thickness in centimetres and ρ the acoustic resistance of the absorbing material.

In railway vehicles, plates or mattresses of glass wool or « sillan », pourous rubber (rubber foam), products based on slag wool, asbestos, products with synthetic foam basis, for example « moltoprene » as well as carpets, coconutmatting, and suitably thick curtains are all used as absorbing materials . In Table III, we have given the degree of absorption of the sound as a function of the frequency for certain particularly important materials.

The table shows that for all these materials the degree of absorption is definitely lower at the small frequencies than at the high frequencies. Here again it appears that the fight against the low frequency components of noise is incomparably more difficult than that against the high frequency components. However, this phenomena is not exceptionally important as, as we have already pointed out, the low frequencies affect passengers less. This table also shows that plates of cork or felt are less effective as regards absorption than other materials.

The action of the absorbing materials can be further improved by constructional measures. It has been found advantageous to replace the plywood used to cover the walls which is acoustically hard by softwood fibre board, with holes or slots in it. The total area of these holes or slots should be 20 to 30 % of the total surface. A particularly effective method is to stick these softwood fibre boards on hardwood fibre boards, which have been perforated in the same fashion. It is also a good practice to stick absorbant materials of different hardness together. The sound absorbing effect can in addition be further increased by arrranging behind the perforated board at a suitable distance some absorbing material of suitable thickness. In the same way, an absorbant material suspended in the form of a garland will help to lessen the noise due to air vibrations.

Experience has shown that the use of sound absorption measures is becoming more and more important in the construction of vehicles. In particularly noisy places, such as the driving compartments and machinery compartment of locomotives, the fight against noise cannot be effective unless the fullest possible use is made of absorption methods.

Taken as a whole, the absorbing materials used should meet the technical conditions given in detail in the chapter dealing with insulation. In addition, they must meet the special conditions of railway vehicles.

Arrangements intended to reduce noise used on up-to-date motor rakes and Diesel locomotives.

After the war, the Deutsche Bundesbahn studied systematically the problem of noise in connection with the construction of railway vehicles, making use of the knowledge already obtained in the allied fields of ship and aircraft construction. Many measurements carried out on vehicles when stopped or running, with and without sound insulation, have enabled them to acquire a deep knowledge of the acoustics of vehicles (3).

(3) TASCHINGER : « Der gegenwärtige Stand in der Untersuchung des Geräuschsproblems von fahrenden Eisenbahnwagen », *Glasers Annalen*, 1951, Nos. 10 and 11.

TABLE III. — **Degree of absorption of several important absorbant materials.**

	Thick-ness in cm	Percentage of absorpt on for frequencies of					
		128 Hz	256 Hz	512 Hz	1 024 Hz	2 048 Hz	4 096 Hz
Mattress of glass wool or Sillan wool of 50 kg/m³ on a hard partition	4	11	30	60	80	92	94
with an air space of 3 cm (resonance).	4	25	60	85	100	100	100
Rigid Moltoprene plate on a hard partition.	2	20	40	55	70	81	86
Elastic Moltoprene plate on a hard partition	2	10	20	52	99	92	100
Cork plates	2	8	2	8	19	22	22
Iporka on a hard partition	6	12	29	55	67	62	85
Ultralite plate on a hard partition . . .	2.5	18	40	44	63	80	80
Felt on a hard partition	5	9	12	18	30	55	59
A carpet on the floor	5	4	4	15	29	52	59
For comparison : person in a coat sitting on a chair . .	—	21	30	45	58	71	—

This has been applied for the first time in the construction of the long distance 1 000 HP triple Diesel rakes and the 2 000 HP Diesel locomotives.

1 000 HP triple Diesel rake for long distances.

The long distance triple Diesel rake with hydraulic transmission, with a maximum speed of 140 km (87 miles)/h (série 08.5) (fig. 3) consists of a motor unit, a central coach and a driving coach, all of which are eight wheelers. The 1 000 HP Diesel engine with hydraulic transmission is mounted on the bogie of the motor unit. The motor unit also includes in addition to the driving compartment, the machinery compartment, the luggage compartment and mail compartment, as well as the kitchen and its office and the dining-room. The dining room is about 11 m (36′ 1″) away from the engine room. These two compartments are separated by the luggage and mail compartment, the staff entry vestibule, the kitchen and the office. The luggage compartment and the dining room are both closed by a door. The middle unit consists of ten 2nd class compartment; the driving unit, eight 2nd class compartments, a conference room and a driving compartment.

The three units are of light weight welded construction. In running order with the motor equipment and fully stocked up, the 80 m (262′ 5 ¾″) long rake weighs 119 t. The saving in weight compared with the pre-war types is about 35 %.

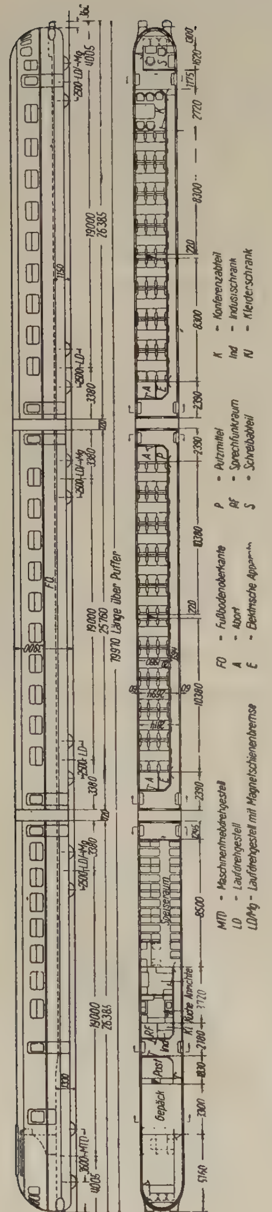

Fig. 3. — Long distance Diesel-hydraulic triple rake.

N. B. — Länge über Puffer = length over buffers. — Küche = kitchen. — Anrichte = office. — Gepäck = luggage. — Speiseraum = dining room.

MTD = motor bogie. — LD = carrying bogie. — LDMg = carrying bogie with electromagnetic brake on the rail. — FO = upper level of floor. — A = toilet. — E = electrical equipment. — P = cleaning equipment. — RF = wireless compartment. — S = office compartment. — K = conference compartment. — Ind = cupboard for equipment Indusi. — Kl = cupboard for clothing.

Extent, nature and methods used to reduce noise.

The sound-proofing measures required for a given vehicle are to a large extent a function of the metallic construction of the body of the vehicle. In the long distance rake, for the first time a shell of thin welded sheet has been used in the construction (4). The influence of the constructional arrangement adopted for the body on the transmission of noise and the risk of the sheets rattling is shown particularly clearly in figure 4. The outer covering in 1 to 1.5 mm sheet, which completely encloses the framework, is made rigid in the floor and roof by thin walled hoopsticks and in the case of the walls by uprights of folded sheet which are also thin. The light construction is extremely unfavourable from the acoustic point of view owing to its small weight. Thin sheets have a greater tendency to rumble than those of a certain thickness. The sheet covering in the vehicle completely like a tubular shell greatly encourages the transmission of the sonorous vibrations of the solid parts. From the point of view of the fight against noise, the construction as a shell of thin sheets would be a disadvantage if it did not have the advantage of a double floor : the floor of the coach itself and the covering brought down and fitted underneath it. The floor of the coach divides the tubular shell of the body into two layers : the spaces above the floor, consisting essentially of the passenger compartments, and the space between the floor and the false floor. This false floor has revealed itself as extremely effective from the point of view of the fight against noise. Unfortunately it is only possible to have it in the portion between the two bogies of a

(4) TASCHINGER : « Die schweisstechnische Konstruktion der Motortriebfahrzeuge der Deutschen Bundesbahn unter besonderer Berücksichtigung der Leichtbauweise. » *ETR*, 1954, No. 6.

vehicle. Above the bogies, where the noise level is several phons higher than between them, for this reason extra acoustic insulation must be provided. The inconvenience from the acoustic point of view of the construction in thin sheet has been eliminated as we shall show in detail further on, by relatively simple means.

In the long distance triple Diesel rakes, the following sound-proofing materials have been used :

1) glass wool mattresses or plates. This material looks like a sort of felt and is impregnated with a special binder with a bituminous base. Glass wool products stand up particularly well to mechanical

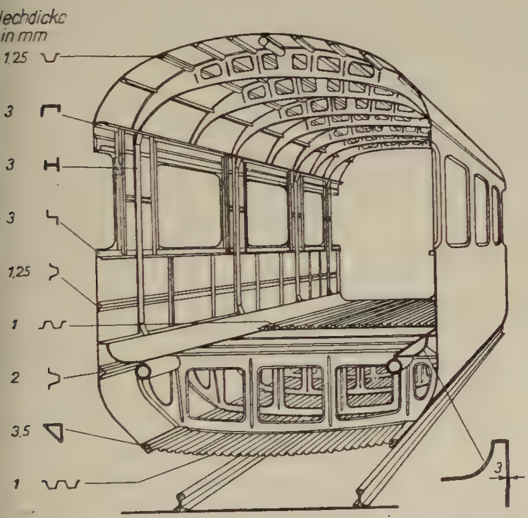

Fig. 4. — Transverse section of the body.
N. B. — Blechdicke in mm = thickness of sheet in mm.

stresses and vibrations. They do not undergo any modification in structure or elasticity as a result of ageing, so that their acoustic properties always remain the same, even after they have been in service for several years. Products based on glass wool are not hygroscopic and have no capillary action, in other words, they do not absorb or retain moisture : consequently they do not undergo any modification as a result of humidity. They have no corrosive effect upon the body nor do they corrode themselves; they have no smell, do not rot, and they are not attractive to bacteria; they are also a thermal insulation. The glass wool mattresses and plates are manufactured in various thicknesses and densities; they can be cut to size as required. Their specific weight varies between 50 and 150 kg/m^3. Cavities can be stopped up with glass wool. Glass wool mattresses are also made in strips and sewn onto water-resistant crepe paper or on galvanised metallic fabric and completely covered with a closely woven muslin. To insulate floors, etc., insulating plates of great density (150 kg/m^3) are used bound together with synthetic resin;

2) Cork mixed with tar — also known as « expansit » cork; this consists of granules of expanded cork bound together with bitumen or coal tar pitch. In the long distance Diesel rakes, bitumin is used as the binder. Cork materials of this type have a very low weight and at the same time serve as a thermal insulation. The mixture of tar and cork is put into the hollows of the corrugated sheeting of the floor;

3) antivibrine, asbestos flock as a sound-proofing material. Antivibrine is an emulsion of bitumin in a special solvent. The antivibrine used in the construction of the railcars is air-dryed. The thickness of the layer is reduced by 40 % when it is dry. Asbestos is an amphibole which occurs in the form of fine fibres. Asbestos fibres are sprayed on in conjunction with a binder.

1. *Frame.*

In the frame of a bogie vehicle, there are three different zones to be distinguished from the point of view of noise :

a) the end of the frame including the portion over the bogie up to the false floor;

b) that part of the frame which is duplicated by the false floor;

c) the adjoining portion of the frame above the second bogie to the other end of the vehicle.

The noise of running is most pronounced in the immediate vicinity of the bogies. In these zones, additional protective measures have to be provided. In the triple Diesel rakes, the central coach is coupled to the motor unit and to the driving unit by a rigid coupling. The overhang of the coaches is 3 380 mm (11′ 1″) and the distance between the ends of adjoining coupled coaches only 720 mm (2′ 4 3/8″). At the coupled-up ends the adjoining bogies are only about 5 m (16′ 5″) apart. The coupled-up ends are therefore also in the noisiest area and require additional protective measures. In the part of the frame between the bogies, where there is the false floor, the running noise diminishes as the centre of the coach is reached; in this part, simpler protective measures are adequate.

The height of the floor is 1 150 mm, the play of the body and axle springs 100 mm and the diameter of the wheels 930 mm, so that the free space above the bogies and under the frame is extremely limited. It was soon clear that the only way to reduce the noise sufficiently was to fill all the free space up completely with sound-proofing material.

The coaches of the triple motor rake are fitted with side and front petticoats which carry on the walls below the frame. The bottom of these petticoats is 275 mm above rail level. Between the bogies, the ends of the two side petticoats are connected together by a base in corrugated sheet. At the ends of the false floor, closing-in sheets are arranged perpendicularly to the longitudinal centre line of the coach which connect the false floor obliquely to the frame and together with the side petticoats and the base in corrugated sheet form a completely closed-in box. The smooth walls prevent the formation of wind noises.

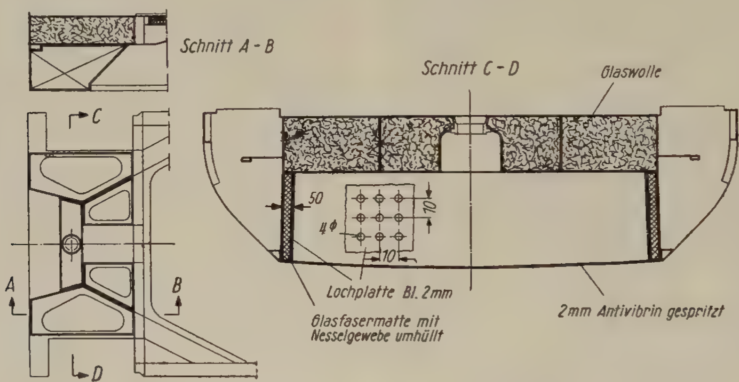

Fig. 5. — Protection against noise in the buffer beam of the frame.

N. B. — Schnitt = section. — Glaswolle = glass wool. — Lochplatte... = perforated sheet, 2 mm sheet. — Gespritzt = sprayed on. — Glasfasermatte... = mattress of glass wool in a muslin case.

The triple railcars are mounted on carrying bogies with inside axle boxes, which take up less room in front of the wheel discs than bogies with outside axle-boxes. The lateral petticoats can therefore be extended over the carrying bogies as well. The space available makes it

possible to curve vertically downwards the lower flanges of the main cross members of the frame at both ends and to extend them as far as the triangular beams of the lateral wall petticoats. In this way, there are spaces between the lateral petticoats and the sheets of the lower flanges which are used for insulating the noise of the wheel discs. In front of the motor bogies, which have external axle boxes, shutters have been fitted in front of the boxes which open elastically towards the outside.

The Scharfenberg automatic coupling with central buffer has been fitted at the front ends of the coach. The dimensions of these couplings, with their vertical and transversal displacements take up a lot of room. It was therefore necessary to provide a sort of big trough which is closed in by sheets at the back, above and below, and open towards the end of the coach.

The two headstocks of the coaches are made up of a complicated type of girder, with an upper and lower flange and welded webs. The latter are so arranged as to allow of the rational installation of the coupling with central buffer and of transmitting to the frame and side walls the traction and compression stresses exercised by this latter. The main beam forming the body bolster also consists of a welded box girder. Between the ribs and web of the overhanging parts there are a certain number of spaces. In order to reduce the weight, hollows of various sizes have been made in the sheets. The corrugated sheeting of the floor rests on the upper rib.

In the end headstock, the spaces in the sheet beams have been completely filled in with bulk glass wood. The hollows in the sheet of the lower ribs of the box girders are covered with 0.8 mm thick sheet which prevents the packing from

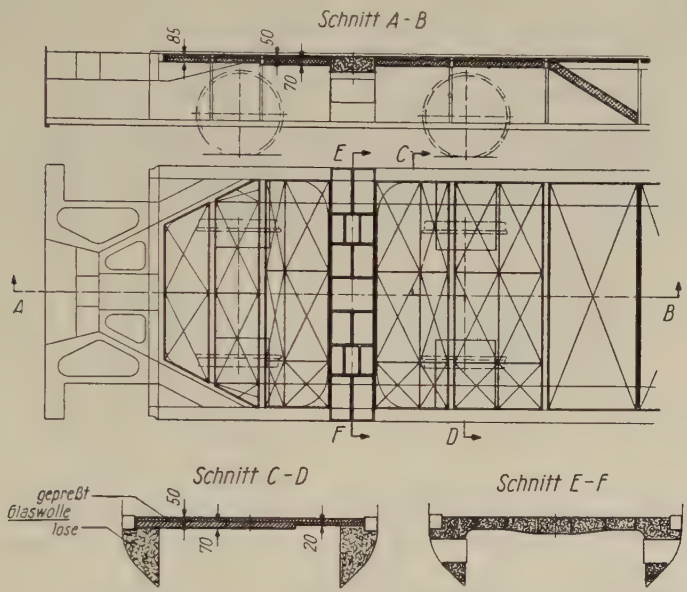

Fig. 6. — Anti-noise insulation of the frame above the bogie.
N. B. — Glaswolle = glass wool. — Gepresst = compressed. — Lose = loose.

slipping and protects it from dust, damp and blows from stones. The steps at the ends of the coaches are covered on two sides and at the back by sheets. These sheets are insulated by a mattress of glass wool 50 mm thick. In order to absorb the noise, these glass wool mattresses are sewn on the outside on a muslin sheet stuck to a perforated sheet and fastened by iron wire. The holes in the sheet are 4 mm in diameter and are spaced 10 mm apart. In the same way, the closing-in sheet which connects obliquely the sheet of the false floor and the lower rib of the frame, is insulated by means of a mattress of glass wool 50 mm thick. In this way, the end of the frame is insulated from the adjoining bogie from the acoustic point of view.

The openings needed for the cables, ducts for compressed air, heating, etc. have been acoustically insulated on both the outside and inside.

That part of the frame lying above the bogie from the front as far as the oblique sheet closing in the lower compartment is insulated by means of two layers of glass wool mattress, completely enclosed in closely woven muslin, the upper layer being 50 mm thick and the lower layer 70 mm. At the bottom, the glass wool mattresses are covered with a steel sheet 1.25 mm thick. In the immediate vicinity of the wheels, the glass wool mattresses are hollowed out in the shape of a trough. The covering layer is reduced at this point to 20 mm so that the total thickness of the two layers is still 70 mm. The body bolster carrying the bogie pin is completely enveloped in glass wool over its whole length. The spaces in the frame in front of the wheels formed by the lower flange of the main cross member extended downwards and the petticoats of the side walls are also filled in with glass wool, and the lightening holes in the sheets are covered in with thin sheets.

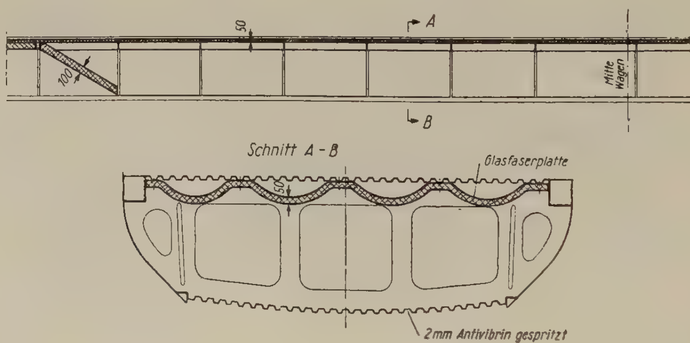

Fig. 7. — Anti-noise insulation of the frame above the false floor.

N. B. — Glasfaserplatte = glass wool plate. — Mitte Wagen = centre line of vehicle.

The anti-noise devices used in the part of the frame above the false floor differ considerably from those used in other sections of the frame, where it is essentially acoustic insulation that has been used. In the central part, the noise becomes less and less towards the middle of the coach. The opening made in this part is enclosed towards the bottom by the false floor, 1 mm thick, laterally by the petticoat sheeting 1.5 mm thick, and at the top by the 1 mm sheet of the floor which is carried by the frame. The whole is made rigid by 2 mm thick members. At the two ends there are the

1 mm thick oblique sheets which connect the false floor to the frame. Trials at a fixed point have shown that a considerable part of the outside noise is absorbed by the false floor which is not acoustically insulated, whereas the floor above it only damps out a much smaller proportion of the noise (5). Less anti-noise protection will therefore suffice in the case of the floor of the wagon. Here a 50 mm thick glass wool mattress has been placed under the corrugated sheeting of the floor over its whole length, except in the centre portion of the coach and above the battery compartments. In the first case, this arrangement had to be foregone because this is where the heating equipment of the coach is located, which is oil-fired, but there is no inconvenience as this is the place where the noise is at its minimum intensity. In the second case, the batteries took up too much room to permit it.

The sheeting of the petticoats, the corrugated sheeting of the false floor and the corresponding members are soundproofed by spraying them with a 2 mm thick coat of antivibrine. The two oblique sheets at the end, which are subjected to the intense sonorous vibrations of the air from the adjoining bogies, are covered with a glass wool mattress 100 mm thick in an envelope of air-tight muslin fabric. These mattresses are stuck to the oblique sheets to prevent them rattling. In the compartment formed by the false floor, resonance may occur which under certain conditions may diminish or even cancel out the anti-noise effect of this arrangement. To insulate them, the 50 mm thick mattresses under the frame are suspended in the form of garlands in order to absorb the noise.

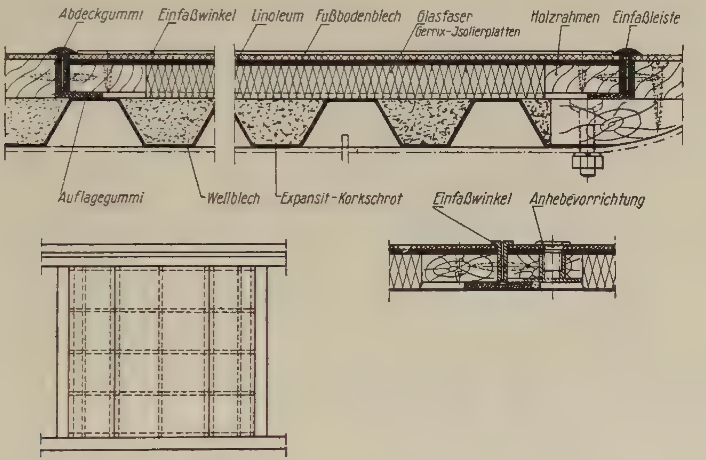

Fig. 8. — « Floating » floor.

N. B. — Auflagegummi = rubber support. — Wellblech = corrugated sheet. — Expansit-Korkschrot = « Expansit » cork granules. — Abdeckgummi = rubber joint cover. — Einfasswinkel = frame angle. — Fussbodenblech = floor sheeting. — Glasfaser Gerrix-Isolierplatten = Gerrix glass wool insulating plates. — Holzrahmen = wood frame. — Einfassleiste = frame moulding. — Anhebevorrichtung = lifting device.

The fitting of anti-noise materials is much less convenient in the motor unit.

(5) See article quoted in footnote 3.

Here the space between the floor and the false floor is almost completely filled up by the batteries, commutation equipment, compressors, fuel and oil tanks, etc. All that could be done therefore was to place a 100 mm thick glass wool mattress with a muslin cover and metal trellis under the floor, though the thickness had to be reduced at a great many points, whilst at others there was no room for it at all. In the same way, a certain amount of difficulty was experienced in spraying antivibrine to the false floor sheeting, the centering of the floor and the side petticoats in the motor unit because should it get into the fuel lines, the antivibrine soaks up fuel and thus is a fire risk. However, the risk of resonance noises being set up in the lower compartment of the motor unit is much less than in the two other coaches, as the mass of air enclosed therein is much less and it is also broken up by the receivers, accumulator sets and other equipment.

In the long distance triple Diesel rakes, for the first time, a « floating floor » has been used (fig. 8) which effectively prevents noises due to the sonorous vibrations of the side walls and frame from being transmitted to the floor. The floating floor consists of a 2 mm thick sheet on which 3 mm thick parquet design linoleum is stuck. The sheet is screwed onto a 15 mm wooden framework in the panels of which insulating plates of glass wool bound together with synthetic resin 18 mm thick are inserted. These plates have a density of 150 kg/m³. They are cut to the desired size during manufacture. They rest on the raised portions of the corrugated sheeting floor and on the cork filler which is used in the hollows. The different panels of the floating floor are separated from the side walls and intermediate partitions by a gap 1 mm wide. This method of construction means that there is no metallic link between the floor and the side walls and frame.

2. *End and side walls.*

The end and side walls of the coaches consist of an outer sheet 1.5 mm thick stiffened by a closely knit framework of folded sheets 1.25 to 3 mm thick. The windows of the side walls are 1 200 mm wide and 900 mm high in the case of most of the compartment windows. The lower part of the window, which are set level with the side wall, do not slide, so that there is no need to allow for any space in the partition below the windows. The upper part which opens upwards towards the curve of the roof requires a housing though only a small one, but this is in the zone where the noise is reduced. As far as protection against noise is concerned, it is most important that the whole of the wall below the window sill should be available for insulation. The articulated doors, most of which are at the ends of the coaches, also do not need any space in the walls, because when open they slide in front of the side wall; here again the usual anti-noise measures are not sufficient. The retractable steps are raised automatically when the doors are closed; they fit (which is advantageous from the sound-proofing point of view) into the extension of the side wall petticoats. The front windows on the driving compartments are relatively small. At the coupled ends of the coaches, on the other hand, there are some large openings (1 190 × 2 000 mm) for intercommunication, which make sound proofing extremely difficult.

The outer covering of the walls of the long distance triple Diesel rakes are 50 mm from the inside walls which consist of sheets of plywood. The space between the sheet and plywood partition can be used for sound insulation. For this purpose, sound-proofing bands 100 mm wide of Gerrix glass wool are used which weigh about 110 kg/m³ sewn between bands of water-resistant crepe paper and enclosed in tightly woven muslin. To prevent the outer sheets rattling, the bands of glass wool are stuck to the out-

side sheeting, whereas the interior cover compresses the glass wool mattress and reduces its thickness from 70 mm to 50 mm. The different sound-proofing bands of glass wool are stuck to the outer sheeting at even spaces of about 225 mm so that each of them is as far as possible from the beams of the lateral framework of the coach, in other words, within the area of maximum flexion oscillations. Sonorous air vibrations which have penetrated into the space between the different bands of glass wool are absorbed by these bands. Trials have shown that it is sufficient to cover one third of the spaces in the side walls with bands of glass wool provided that these bands are arranged as described above.

Additional sound-proofing measures have been taken in the case of the end walls and the side walls in the corridors and entry vestibules. We will deal with these later. At the closely coupled ends, the end walls, as we have already said, have some large openings in them for passing from one vehicle to the other. The different coaches of the long distance triple rakes are connected together by rubber bellows. These rubber bellows cover the whole of the outside of the two coach ends (in other words, the top, the sides and the bottom). But the rubber sheet is only 3 mm thick, so has no sound-proofing effect at all. The very loud noise in this area is able to penetrate directly into the end vestibules of the coaches. Acoustic insulation of the end walls is only effective if the openings in the ends are closed by tightly fitting noise-proof doors (fig. 9). The long distance Diesel rakes are fitted with double sliding intercommunication doors made of light metal,

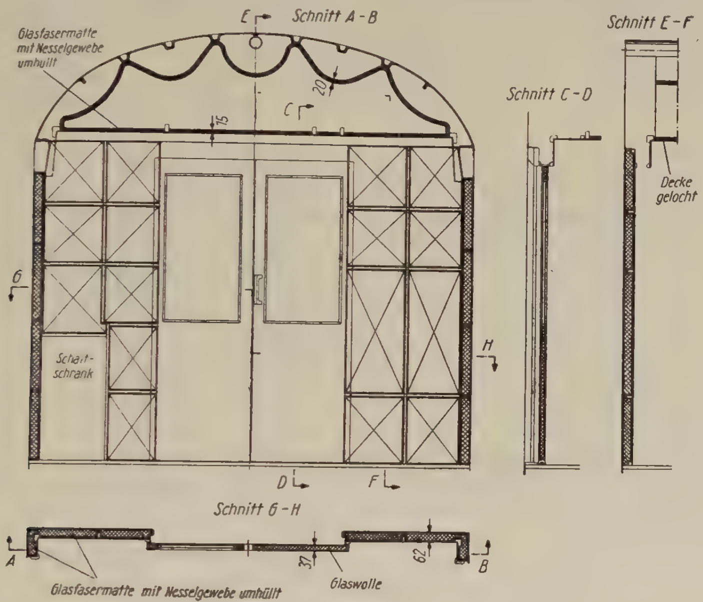

Fig. 9. — Acoustic insulation as fitted to the front of the coach at the coupled end.

N. B. — Decke gelocht = perforated ceiling. — Schaltschrank = equipment cupboard. — Glasfasermatte... = glass wool mattress wrapped in muslin.

and noise-proof, of the Kiekert type. The two sheets forming each half door are 60 mm apart. The hollow space between the two sheets and the framework of the door is completely filled up with glass wool. The windows in the door are double. The doors are in addition made hermetically tight by double rubber fittings and as far as the bottom half is concerned by double brushes on the outside. The considerable weight of doors of this kind makes it difficult to open and shut them, so that passengers who have opened them are often unable to shut them. But as the acoustic insulation provided by the closed doors is essential, they have been fitted with electric control which is unlocked by the door handle. This device not only governs the opening of the doors but in addition closes them automatically after a short period which is set at 2 to 3 sec. The part played in the acoustic insulation by the communicating doors of the rake is therefore always assured.

The windows of the compartments in the long distance triple rakes have also been included in the anti-noise campaign (fig. 10). To date, it has been the general practice to use sliding windows. This type of window meet the wishes of passengers but has many drawbacks, one of the greatest of which is that if the windows are to open space must be provided for them in the side walls under the windowsill. Rain penetrates into the space and leads to corrosion of important parts of the frame and body. Sliding windows cannot be hermetically sealed except with great difficulty, also they do not entirely prevent draughts. The glass radiates cold; in bad weather it mits over and loses its transparency. But the greatest drawback is that outside noise penetrates into the passenger compartment at practically full strength owing to the lack of airtightness and because the window housing cannot be insulated. The windows with the best insulation are those with double panes because these can be made to fit perfectly hermetically into the side walls. But fixed windows mean that mechanical air conditioning must be provided and at the present time this is still very expensive; in addition, fixed windows are much criticised by passengers who much prefer sliding windows. The type of window used for the first time by the Deutsche Bundesbahn on the long distance triple Diesel

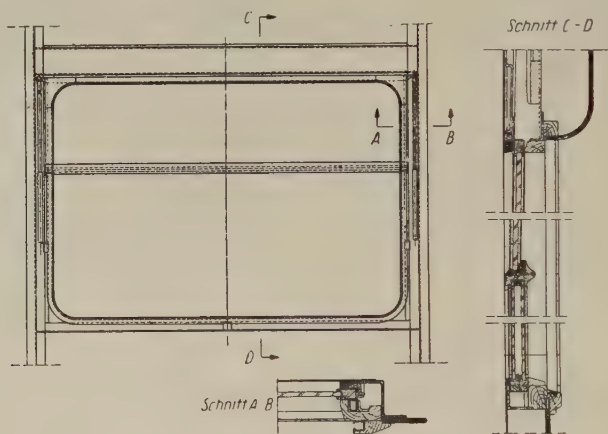

Fig. 10. — Soundproof compartment windows.

rakes consists of a fixed lower portion with double panes and an upper portion of 7 mm thick unframed glass which opens; this is a compromise which obtains most of the advantages of a fixed window without giving up the possibility of opening the window. The fixed part of the window is 556 mm high and the total height of the window is 859 mm. The fixed frame consists of two panes of 4 mm thick glass 10 mm apart, which gives perfect insulation with air imprisoned between them. The upper portion is 316 mm high and can be opened by means of a handle.

Measurements have shown that with this type of window a noise reduction of about 4 phons is obtained. This appreciable improvement must be attributed essentially to the better fitting window, to the double panes and the absence of a housing in the wall. Sound insulation can be further improved by increasing the air space between the two panes. But if the distance is increased, it becomes harder to make them airtight. However, the improvement of insulated windows must continue to be sought on the lines of a greater air space between the two panes.

To protect the inside of the coach from the outside noise of the vehicle, the windows must be perfectly closed whilst running. Only a very small air stream is needed to increase considerably the noise inside the compartment. If one window in a compartment is wide open, all the outside noise of the vehicle will be perceptible inside the compartment almost unattenuated. All the sound-proofing measures taken will only be effective therefore if all the windows, entry doors and communicating doors between the coaches, as well as the corridor and compartment doors are kept closed whilst the train is running. By seeing that this is done, the passengers themselves can assist in the anti-noise campaign.

3. *Roof.*

The roof is a 1.25 to 1.5 mm thick sheet and is made rigid by means af a close network of thin folded sheets. On the inside of the roof sheet, over the whole length of the vehicles, a 5 mm thick layer of cork has been sprayed. The carlines and purlins have been coated in the same way. The ventilating devices in the roof often give rise to appreciable wind noises. To avoid this, such devices have been doubled by an outer envelope. The space thus formed has been filled with glass wool.

4. *Measures taken for sound absorption within the vehicle.*

The side walls and ceilings of the vestibules and corridors in front of the compartments of the long distance Diesel rakes are lined, as is the usual practice, with polished sheets of plywood. But spaces covered with plywood and in addition broken up by many windows are noisy. Their acoustic hardness makes plywood sheets extremely bad from the noise point of view. Inside noises penetrating into the vestibule and side corridors can only be reduced if absorption measures are also taken. The ceilings, end walls, side walls, doors of cupboards in the vestibules, etc. can all be made to absorb sound. In order to make use of acoustic absorption, plates of perforated hardwood fibre are used for the ceilings of the vestibules and corridors, having a great number of 4 mm dia. holes 10 mm apart (fig. 11). In the space between the ceiling and the roof absorbant glass wool mattresses 20 mm thick have been fitted, sewn on a metal trellis of galvanised wire and on a closely woven muslin cloth. These are suspended in the form of garlands. In the side walls of the vestibules, between the entry door and the side corridor door, perforated hardwood fibre boards of the same sort have also been used. In the space between the inside fibre board and the outer sheet,

a wooden grill has been inserted; its panels take the insulating glass wool plates which according to the size of the space are 20, 50 or 70 mm thick and are covered on the inside with a dustproof muslin. The spaces in the door stiles are also packed with glass wool. In the same way sheets of perforated hardwood fibre board have been used for the equipment cupboards and cleaning equipment cupboards, behind which glass wool mattresses are fitted.

The sound absorption measures taken in the side corridor are on the same lines : perforated ceiling and behind this, under the roof, an absorbant mattress

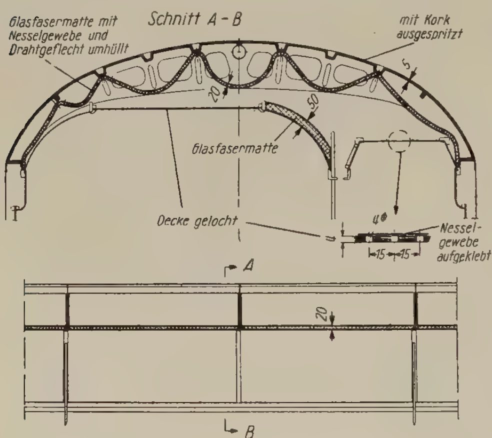

Fig. 11. — Measures introduced to absorb noise under the roof.

N. B. — Decke gelocht = perforated ceiling. — Glasfasermatte = glass wool mattress. — Nesselgewebe aufgeklebt = stuck on muslin cloth. — Mit Kork ausgespritzt = cork flock. — Glasfasermatte mit Nesselgewebe... = glass wool mattress wrapped in muslin with a metal trellis.

suspended in the form of garlands. The swing doors of the corridor are fitted with air-tight strips at top and bottom; with a double rubber fitting on the side and on the side of the hinges with an hermetic sealing strip.

Special absorption devices in the second class passenger compartments — here again it is possible to use perforated ceilings and suspended absorbant mattresses — would only be successful under given conditions. Here, in fact, the soft cushions, covered in plush, absorb the noise to a certain extent. It is particularly in the compartments which pick up the loudest noises that effective action is required of the absorbant materials. This is why in the centre coach, the two end compartments which are the noisiest compartments have been equipped with an absorbant ceiling. In the vehicles with large third class compartments, where the headrests of the seats are covered in synthetic materials, a further reduction in the noise should be possible if the ceiling, roof, partitions and side walls were made absorbant as described above.

5. *Reduction of noise in the other parts of the vehicle.*

Amongst the other measures taken in the campaign against noise in the long distance triple Diesel rakes, mention must also be made of the streamlined form of the ends of the coaches, the smooth outer surfaces of the roof and sides, the lateral petticoats, the false floor and the rubber bellows all following the line of the coaches. As there are no projections on the outside of the vehicle and the equipment, receivers, accumulators, compressors, etc. are all housed under the floor and surrounded by a smooth surface, there are no wind noises. Particular care has been taken to seal all the doors and windows hermetically by effective rubber sealing strips. Thanks to the adoption of disc brakes with a short and simple rigging, the noise due to the rigging and the well known noise of brake shoes are completely avoided.

The mounting of the bogie centres of the carrying bogies with inside boxes on rubber and the insertion of rubber between the lateral supports of the body and the bogie frames prevents to a large extent the transmission of the sonorous vibrations produced by the wheels being transmitted to the body.

The extra weight involved in the campaign against noise.

The amount of weight involved in acoustic insulation is fairly considerable. Table IV, for example which gives the increase in weight for the additional materials in the case of the centre coach of the long distance triple Diesel rake, makes this clear. This shows that effective acoustic protection in the case of an eight wheeled vehicle of second class compartments adds more than two tons for the insulation and increases the cost by about 5 % of the cost of the vehicle. But this increase in weight and cost, though not negligible, is counterbalanced by the appreciable results obtained in the anti-noise campaign.

TABLE IV. — **Weight of materials needed for the anti-noise campaign in the centre coach of a triple Diesel rake.**

Insulated portions of the coach		Iusulating materials	Weight in kg	
			part	total
Frame	above false floor above bogie above hoods	Glass wool mattress	245 160 20	900
	Sheet of false floor	Antivibrine sprayed on	210	
	Floor of corrugated sheet	Cork granules with lime asphalte	265	
	Additional weight compared to fixed floor	sheet and insulating glass wool mattress	560	560
Outside walls	Side walls between vestibules Side walls of vestibules End walls	Glass wool mattress	130 15 15	160
Inside walls	WC partition and corrugated sheet partitions		10	10
Roof		Cork sprayed on	180	180
Spaces above the ceiling	Above corridor and compartments Above vestibule	Glass wool mattress	285 60	345
Total weight of acoustic insulation				2 155

The phonic results of noise reduction measures.

On one of the long distance triple Diesel rakes the true reduction in noise has been checked by means of the special measuring wagon of the Deutsche Bundesbahn's vehicle testing department. For the sake of clarity the following report is limited to the studies made on the central coach of the rake; in the motor coach and the driving coach, the measurements showed that in the case of the passenger compartments, the noise was about the same as that in the central coach. As this centre coach consists entirely of passenger compartments, these results are to a certain extent applicable to passenger coaches.

The trials on the line were carried out on the acoustic test line of the Vehicle Testing Department, which is also used for measuring the running qualities of vehicles. This section includes sufficiently long portions of rails with or without undulatory wear; the state of maintenance of the track is only fairly good on certain portions. It was therefore also possible to measure on this section the relationship between running quality and the formation of noise. During the trials, the speed was maintained constant at 80 km (50 miles)/h, a speed which has the advantage of being attainable with a moderate tractive effort after a short starting up period. At this running speed, vibrations due to sound are sufficiently marked. As the relationship between the sonorous intensity of noise and the running speed is known, it was not necessary to carry out trials at higher running speeds. Picking up the sound levels in the air was done by means of condensor microphones. The measurements give full details of all the exterior and internal noises noted at all the important parts of the vehicle. The intensity of the sound was in each case measured in phons. In each case, the frequency of the different sounds was determined with their sonorous intensity in decibels.

1. *Outside noises.*

The nature and intensity of the noises occurring at each point of the vehicle are a function of the noise reduction methods applied. It was therefore necessary to obtain a clear picture of the outside noises reaching the outer surfaces of the vehicle. For this reason, during the running trials, a great number of measuring points at all the important parts, distributed over the whole of the outside surface of the coach were used (false floor and frame, sides, end walls and roof).

a) Exterior noises under the coach.

In figure 12, the distribution of the noise levels under the coach and in the false floor are shown. The measurements were taken at nine points in all under the body of the coach : extremity of each bogie (points 1 and 9) beginning and end of the false floor (points 2 and 8) and at five points at regular intervals on the outside of the false floor (points 3 to 7). The graph shows that the outside noises vary in intensity along the coach. They are at their maximum in the parts forming a sort of hood over the bogies where on rails showing undulatory wear they attain 123 to 126 phons : this is practically the point at which noise becomes painful. The maximum sonorous intensity (126 phons) occurred at point 9, i.e. in line with the rear bogie in the direction of running. This exceptionally high level of noise is due to the incidence of sound on the rear covering of the hood. The extremely high intensities of sound measured above the bogies show clearly the need of providing particularly effective insulation at these places. This also applies to the portion between the end of the coach and the bogie. Towards the centre of the coach, the exterior noises diminish progressively; in the centre of the coach they are 119 phons. The curve of the noise levels measured on a line without undulatory wear show a similar variation; however, the intensities of noise measured are less than on

lines with undulatory wear, the reduction being 13 phons above the bogies and even 16 phons above the false floor. We will return later on in detail to the distribu-series of measurements were taken over the total length, one half-way up the petticoat, one at window level and the third at the beginning of the roof

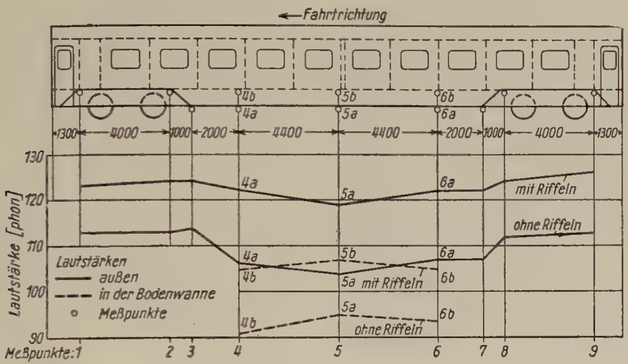

Fig. 12. — Distribution of the level of noise under the coach and inside the false floor at a running speed of 80 km (50 miles)/h.

N. B. — Lautstärke = intensity of noise. — Aussen = outside. — In der Bodenwanne = inside the false floor. — Messpunkte = measuring points. — Fahrtrichtung = direction of running. — Mit Riffeln = with undulatory wear. — Ohne Riffeln = without undulatory wear.

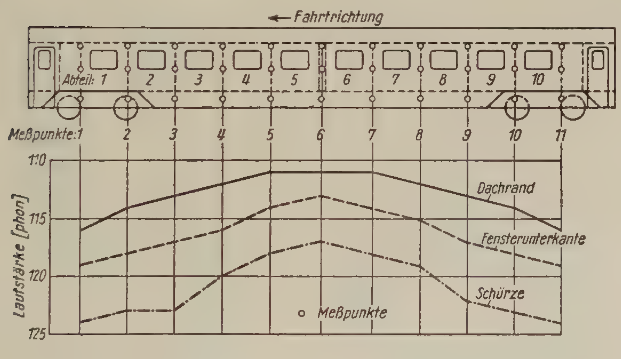

Fig. 13. — Distribution of the exterior noise level along the sides of the body on lines with undulatory wear at a speed of 80 km/h.

N. B. — Dachrand = edge of roof. — Fensterunterkante = window frame. — Schürze = petticoat.

tion of the sound levels in the false floor which are reproduced in figure 12.

b) Exterior noises along the walls.

On one wall of the centre coach, three curve. Each series of measurements covers 11 measuring points, all where the compartment partition joins the side wall. The microphones were attached to the

wall, being 8 cm away from it. The trials having been made during calm weather, the results of the measurements can be applied to the other side of the coach with sufficient accuracy.

The distribution of the level of the outside noises along the side of the body on a line with undulatory wear (fig. 13) shows that outside noises are still at their maximum over the bogies, and decrease towards the centre of the coach. The maximum level is at the bottom of the body and the noise decreases progressively towards the roof. The noises are at their minimum in the roof. The difference between the lowest point of the body and the curve of the roof may be as much as 10 phons. On the petticoat in front of the bogies, intensities of 122 to 124 phons were measured; in the centre of the coach 117 phons. At the bottom of the windows, the intensities of noise oscillated between 119 and 113 phons, whereas at the beginning of the roof curve the intensity of noise was 116 phons above the bogies reducing to 111 phons towards the centre of the coach. In the bottom series, the difference between the maximum and minimum noise is 7 phons, at window level, it is 6 phons, and at the beginning of the roof, 5 phons.

Figure 14 gives a particularly clear picture of the variation in exterior noise along the profile of the vehicle. The measurements were made at three points : A in the second compartment, B between the 5th and 6th compartments, and C in the 9th compartment. Each measuring point consists of 9 different measuring spots. The intensity of the sound in phons measured at these different points were plotted in the system of coordinates drawn around the section of the body. The curves showing the level of noise given by the values measured give an interesting picture of the exterior field of sound enveloping the coach. It will also be noted on this drawing that the sonorous intensities are at their maximum below the coach. At the bottom of the false floor at point 9, on the petticoat, there is an insignificant reduction in noise of 2 to 3 phons. Along the side wall, the exterior noise falls off to a greater extent from bottom to top : by 6 to 8 phons in the centre of the window, and from this point to the beginning of the roof, by about 5 phons. Although the noise falls off still more by about 2 to 3 phons, it must be noted that in the middle of the roof, the exterior noise is

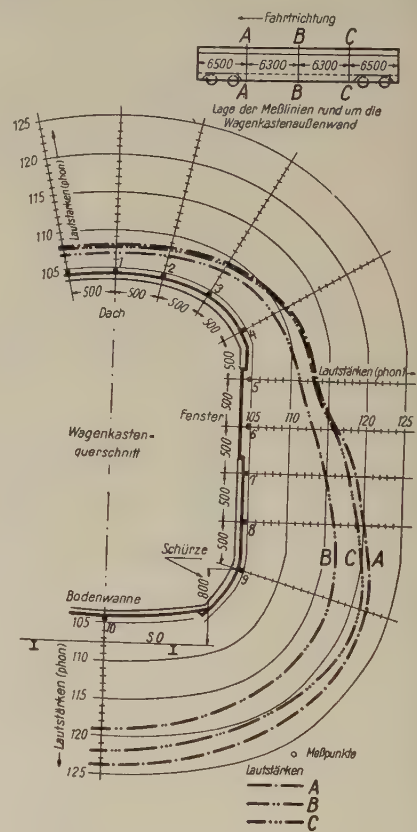

Fig. 14. — Exterior noises recorded at the outside wall of the body on lines with undulatory wear at a speed of 80 km (50 miles)/h.

N. B. — Wagenkastenquerschnitt = section of the body of the coach. — Fenster = window. — Bodenwanne = false floor. — Schürze = petticoat. — Lautstärken = intensity of noise (phons). — Lage der Messlinien... = situation of measuring lines around the outside wall of the body.

still 104 to 108 phons. The graph shows that it is not necessary to apply equally effective sound-proofing measures at all points of the body. It is in the floor and side petticoats that the most effective insulators must be used. But even in the roof it is not possible to do away with sound-proofing altogether, though here the insulattion can be simpler and consequently lighter and less costly. The exterior noise outside the compartment windows, which amounts to 113 to 116 phons, clearly shows that in order to make the passenger compartments quiet, the windows must be included in the anti-noise campaign.

c) Analysis of the frequencies of exterior noises.

The measurements of the sonorous intensity in phons, the results of which have just been reported, are not sufficient to enlighten us as to the sources of the different noises, nor to indicate if certain generators of noise have a particularly strong influence. From measurements of the intensity of the noise only, it is not possible to decide whether the anti-noise measures selected are adequate. Nor do they show whether the elimination of some particularly strong generator of noise would not do away with the need for sound-proofing materials. Therefore, for each measuring point, it was necessary to analyse the frequency by means of sound analysers which show for any given noise the different frequencies with their sonorous intensities in decibels, and thus make it possible to perceive immediately if certain frequencies are more of less marked. The frequency analyses also make it possible to recognise the different sources of the noise, seeing that the frequencies of the more important sources of noise of both vehicle and track are known.

These frequencies are as follows :

noise due to points on the rail	170 Hz
noise due to undulatory wear	420 to 550 Hz
noise of the wheels . .	360 and 720 Hz
rattling of the rigging and heating pipes	700 and 1 300 Hz
resonance of the compartment in the false floor	170 Hz

For example, if the analysis of the frequencies shows a clear point with 720 Hz, this is due to the vibrations of the axles. In this case, some effective method of insulating or eliminating the noise from the wheels must be sought.

In figure 15, analyses of the frequency under the middle of the coach (point 5) and above the bogie (point 2) have been given as examples on lines with undulatory wear. The graph shows that the exterior noises are formed by components of particularly marked frequencies of between 50 and 1 600 Hz. At point 2, above the bogies, frequencies of 360, 430, 460, 520, 720, 850, 1 150, 1 400 and 1 550 Hz are noted in particular. The values of 430 and 520 Hz for example are due to undulatory wear of the rails, those of 360 and 720 Hz to the effects of the wheels; the frequencies of 1 400 and 1 550 Hz lead us to think of the rattling we have mentioned. In the middle of

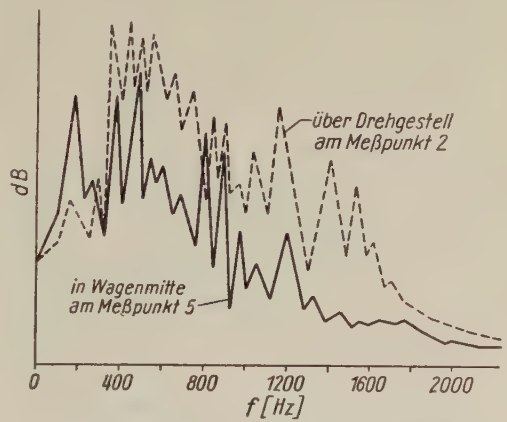

Fig. 15. — Analyses of the frequency of exterior noises under the middle of the coach and above the bogie.

N. B. — Im Wagenmitte am Messpunkt 5 = at the middle of the coach, point 5. — Über Drehgestell... above the bogie, point 2.

the coach (point 5) there are strong components of 170, 380, 480, 800 and 900 Hz. Here again the frequency of undulatory wear is manifest. The frequency of 170 Hz leads us to think of the effects of joint noises. The characteristic noises of the wheels (360 and 720 Hz) are non-existent here. The analysis of the frequencies confirms therefore in its turn that the exterior noises are very appreciable at all parts of the vehicle.

The intensity of the noises in the ten compartments of the centre coach were also measured during running over good sections and sections with undulatory wear of the rails. The microphone was placed in the middle of the compartment, at the ear level of seated passengers. The sonorous intensities measured (fig. 16) show that the noises are very similar in all the different compartments of the centre coach. In the compartments above the bogies, the intensity of the noise is 79 phons when running over rails showing undulatory wear, and 77 phons in the compartments over the false floor. On sections without undulatory wear, the noises measured were 70 to 73 phons, i.e. 6 to 9 phons less than in the previous case. The maximum difference between the noisiest compartment over the bogie and the quietest compartment in the middle of the vehicle is only 2 phons; such a small difference would be inperceptible to the passengers. This result has been obtained by the insulation of the body based on the principles of acoustics. From the point of view of noise in the compart-

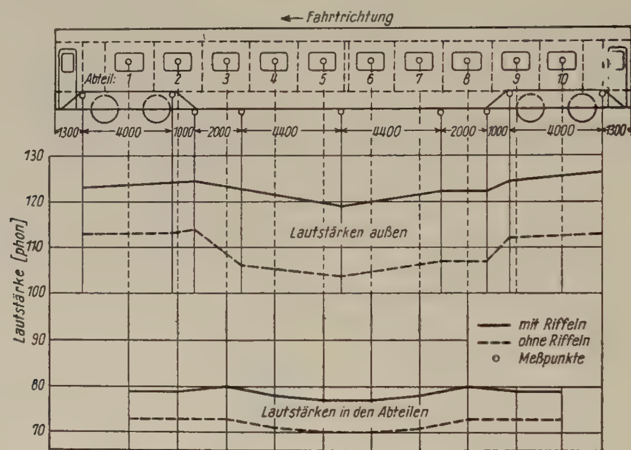

Fig. 16. — Interior noises in the passenger compartments, compared with the outside noises.

N. B. — Lautstärken aussen = intensity of noise outside. — Lautstärken in den Abteilen = intensity of noise in the compartments.

2. *Interior noises.*

It is not possible to judge how successful the measures taken in the anti-noise campaign have been until the intensities of the different exterior and interior noises measured at the same point have been compared. The intensities of the interior noises were measured like the exterior noises at a speed of 80 km/h in all the passenger compartments, in the corridor and in the entry vestibules. In addition, analyses of the frequencies were prepared for all these measuring points.

a) Interior noises in the passenger compartments.

ments, passengers can sit in no matter what compartment of the long distance rakes without their comfort being affected, which is a great advantage in the case of full trains.

In figure 16, the intensities of the exterior noises along the vehicle have also been shown; when running over rails with undulatory wear, they are 42 to 45 phons greater than the interior noises in the compartments, and 34 to 41 when running over rails without undulatory wear. The reduction in noise is therefore considerable.

The distribution of the levels of noise in a compartment has been measured at ten points by means of a movable microphone. The equipment was placed above each seat at ear level of a seated passenger, by the window and by the door, 20 cm above the floor and 50 cm below the ceiling. With an interior noise of 79 phons in the middle of the compartment, it was found that there was the same sonorous intensity above the two centre seats of the compartment. On the side seats (door and window) the measurements gave 80 phons; directly by the window, the intensity of the noise was 83 phons, and by the door of the compartment, 82 phons; it was 83 phons by the floor and 82 phons by the ceiling. One surprising fact was the increase in noise near the ceiling of the compartment. Directly in front of the ventilating slot it was as much as 90 phons. This made it clear that it was essential to insulate the roof ventilators and the ducts according to the technical principles of acoustics.

b) Interior noises in the side corridor and vestibule.

The intensity of the interior noises in the corridor was measured at 11 points (one measuring point in each space between the windows) when running over rails with undulatory wear. According to the curves of the intensity of the noise thereby obtained, at the two ends of the corridor, with the sliding doors at the end and the swing doors of the corridor *shut*, there is a noise having an intensity of 85 phons; towards the centre of the vehicle this intensity is reduced to 83 phons. The intensity of the noise in the corridor exceeds that in the compartments by about 5 phons, i.e. by an insignificant amount. When the end doors were *open* on the contrary, the noise in the side corridor increased appreciably. In the access vestibules at the ends of the coach, the interior noise in this case was 103 phons, i.e. an increase of 18 phons. The intercommunicating doors should therefore always be kept closed whilst running. The electrically operated doors with the device for shutting them automatically guarantees that this important acoustic rule is kept. The well known rattling noises which occur in other coaches, due to the intercommunicating arrangements made of corrugated sheeting, have not been observed, because the stabilising devices at the ends of the close coupling prevent movement between the ends of the vehicle bodies.

c) Interior noises in the false floor.

The noises in the compartment under the false floor (fig. 12) are 105 to 107 phons in intensity when running over rails with undulatory wear, and 91 to 95 phons on rails without such wear, i.e. a reduction of 12 to 14 phons compared with the exterior noises at comparable points. This appreciable reduction due to the false floor has been obtained thanks to the layer of Antivibrine which is 2 mm (5/64″) thick and the 50 mm (2″) thick glass wool mattress suspended in the form of a garland. The insulation of the floor by means of a 50 mm mattress of glass wool further reduced the noise by 26.5 phons.

Analyses of the noise in the hollow of the false floor show that there is a similar variation to that with the exterior noises.

d) Analyses of the frequencies of interior noises.

Analyses of the frequencies of the different interior noises were also established. These show what components of the noise have been insulated, or more or less reduced. The analyses of the frequencies showed very clearly the effectiveness of the sound absorption devices.

Results of the anti-noise campaign in the long distance triple Diesel rakes.

The results of the measures taken prove that the anti-noise materials adopted and the arrangement thereof in the construction of the coaches according to acoustical principles had led to a notable reduction in the noise. With a maximum exterior noise of 126 phons, the greatest reduction of noise in the compartments is nearly 45 phons. Moreover, it should also be noted that the noises due to undulatory wear which passengers find so annoying have been considerably reduced, and can no longer be considered a nuisance. The anti-noise measures taken after careful study and thorough research from the time of their first application in the construction of railway vehicles have been rewarded with a very great initial success. Moreover, the studies have thrown light at what points of the vehicle improvements from the acoustical point of view are still possible. The increase in weight and cost due to noise reduction is far from negligible. It is for the research engineer to reduce such costs without detracting from the acoustic efficiency. The problem of the anti-noise campaign can be considered as solved to a great extent as far as the measures to be applied to the body are concerned. Acoustic research can therefore confine itself essentially to the problems raised by the axles and bogies.

2 000 HP Diesel locomotive.

The 2 000 HP bogie Diesel locomotive with hydraulic transmission for express and freight services (Series V 200) was described in Nos. 6-7, 1953, *Eisenbahn-Technische Rundschau,* under the title : « The 2 000 HP Diesel locomotive of the Deutsche Bundesbahn », by Curt Lampe and Nikolaus Gössl. Its general arrangement is therefore well known. The information given in this article will only be completed in the following report to the extent that this is necessary in order to explain the anti-noise measures used.

The B′-B′ eight wheeled locomotive is 18.5 m (60′ 8 ½″) long over buffers and weighs in working order 62 metric tons, without supplies. This remarkably low weight has only been achieved by making full use of all the known possibilities of light weight construction in the case of the vehicle part (bogie, frame and body). The fact that the frame and body of the vehicle all play their part in the strength of the whole has contributed to the reduction in weight. The frame and body are made up of a girder structure in welded sheet. The two heavy Diesel engines, each of 1 000 HP, the transmission and the heating boiler are mounted on the frame. As such equipment must not be exposed to the effects of any warping, the webs, ribs and sheet covering in the frame, which form its stand, had to be given thickness of up to 6 mm (¼″). In the same way, the framework of the body and the sheet covering the external walls are thicker than on the railcars. The risk of any rattling in the sheets is definitely less in the case of this Diesel locomotive. The method of construction of the frame, in girders of pressed sheet welded throughout, and the body fastened to it by welding, on the other hand encourage the transmission of sonorous vibrations from the metallic parts.

Need for and extent of sound-proofing.

The two 1 000 HP four stroke 12 cylinder engines, revolving at 1 400 r.p.m., the two hydraulic transmissions, the fans of the cooling equipment (one per Diesel) and the two brake compressors are all generators of noises of extraordinary intensity.

At 1 400 r.p.m., the engine on firing produces a noise with a fundamental frequency of 114 Hz; the hydraulic transmission has its own frequency of 1 300 to 1 400 Hz. An important consideration in the anti-noise campaign, the intensity of the noises from the Diesel engine and the transmission depend to a large extent on the speed of rotation and the power supplied. Another difficulty for the anti-noise campaign is the fact that the two Diesel engines, the two radiator fans and the two brake compressors are all installed higher than the exterior noise of the other train. If the noises in the machinery compartment, which have reached the point at which noise becomes painful, penetrate into the driving compartment, this will impose a strain upon the driving staff which might lead to premature ageing.

This brief review of the acoustical position on the Diesel locomotive shows clearly and in a very striking manner the importance and necessity of an effective anti-noise campaign.

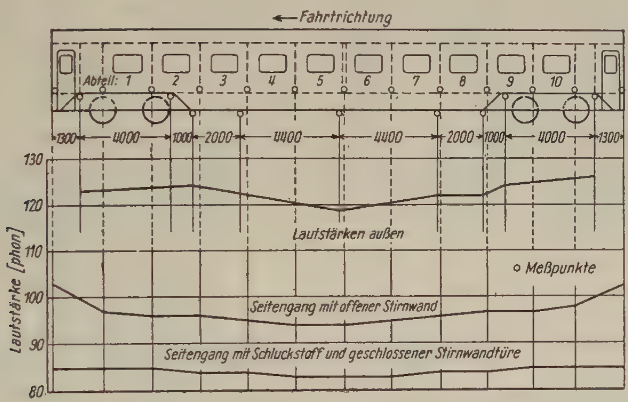

Fig. 17. — Interior noises in the side corridor compared with the outside noises.

N. B. — Lautstärken aussen = intensity of noise outside. — Seitengang mit offener Stirnwand = corridor, end wall open. — Seitengang mit Schluckstoff... = corridor with absorbant material and door in end wall shut.

in a relatively small compartment which is only 10 m (32′ 9 ¾″) long, 3 m (9′ 10 1/8″) wide and 2.8 m (9′ 1 ¼″) high, and the hydraulic transmissions, which must be readily accessible, are fitted under the floor of the driving compartments. In the machinery compartment of the locomotive, the noise is as much as 126 phons; unlike what occurs on the long distance Diesel rakes, their intensity exceeds that of the actual running noises. When passing another train or running through a tunnel, there is no increase of noise on the Diesel locomotive because the noise made by its own engines is

In figure 18, we have shown diagrammatically the mechanical equipment fitted on the locomotive as well as the partitions intended for acoustic insulation.

The machinery compartment is separated from each of the two driving compartments (2) by a partition (1). Immediately behind these two partitions, there is a 1 000 HP Diesel engine (3) followed by a group of radiators with a large and a small fan (4). Between the two groups of cooling equipment is the heating boiler which is oil-fired (5). The Diesel engines, the groups of radiators and the heating boiler can be dismantled

separately from above through special trapdoors (6). The two cooling water tanks (7) are fitted on each side of the heating boiler, while the Diesel oil tanks (8) and the oil for the heating boiler (9) are housed in the frame. The two air compressors (10) for the brakes are fitted in the side corridor of the machinery compartment. The hydraulic partition. It is above the bogie, so in the area where the locomotive running noises are at their loudest. Under the driving compartment floor, which is 1 350 mm above rail level and 730 mm above the flooring of the machinery compartment is the hydraulic transmission. In fighting noise in the driving compartment, it was therefore necessary to take

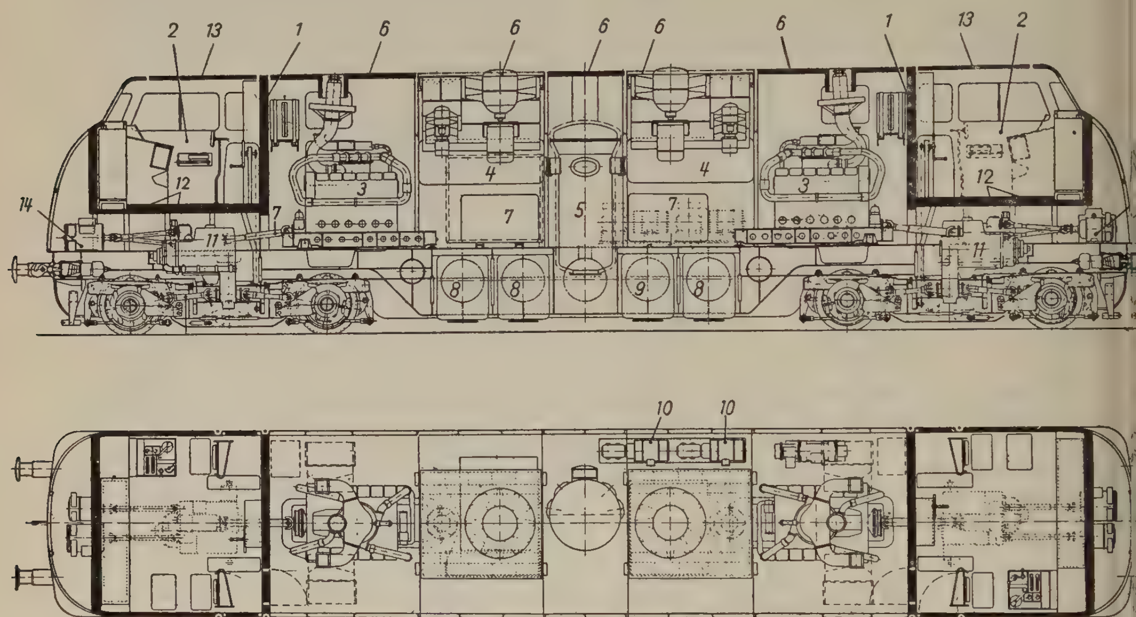

Fig. 18. — V 200 Diesel locomotive with sound deadened walls.

transmissions (11) are housed in the frame, under the floor of the driving compartment, just above the bogies. They can be removed from above through trapdoors (12) in the floor and (13) in the roof. The generators for the fans (14) driven by the hydraulic transmission are fitted in the hood in front of the driving compartments.

Acoustic insulation of the driving compartment.

The driving compartment is next to the machinery compartment at the rear into account both the noise of the machinery and the running noises. As we will explain in detail further on, to get satisfactory acoustic results in the driving compartments it was necessary to make the greatest possible use of all the resources of insulation and noise absorption, with special attention to the need for being able to hear the acoustic signals and verbal instructions of the guard with the windows open and the Diesel engines running.

The floor of the driving compartment consists in fact of thirteen trapdoors

(fig. 19, bottom) which can be raised at will to give access for maintenance purposes to the hydraulic transmission, the cardan shafts of the fan generator and the lighting and starting dynamo, as well as the brake pipes, all of which are mounted under the floor. To avoid sonorous vibration of the air and the solid parts, care had to be taken that the trapdoors in the floor :

1) closed hermetically up against the framework of the floor;

2) had no rigid metal connection with the framework of the floor;

3) were given as thick acoustic insulation as possible, in view of the intensity of the running noises (about 120 phons above the bogie).

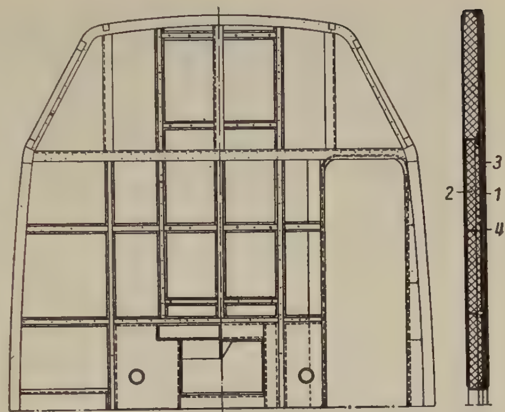

Fig. 20. — Rear partition of the driving compartment.

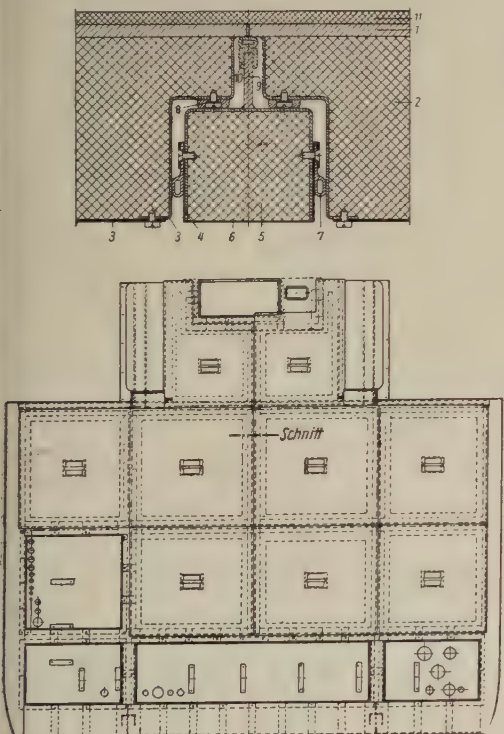

Fig. 19. — Floor of the driving compartment; *below :* view in plan; *above :* section to scale 1 : 10.

In order to save weight, the trapdoors are made of light metal sheets (1) 8 mm (5/16″) thick, under which are fitted mattresses of « Sillan » (2) 115 mm (4 1/2″) thick (fig. 19 top), covered with protective sheeting (3) 1.5 mm (4/64″) underneath and 2 mm (5/64″) thick on the sides. The trapdoors rest on a square framework formed of stringers and stays made of 2 mm sheet pressed into U form (4). The U is also filled in with « Sillan » and closed at the bottom by a protective sheeting (6). On each limb of the beam is screwed a rubber pipe (7), which bears laterally on the protective sheeting (3) of the floor trapdoors. When the trapdoor is closed, it closes hermetically on the framework by means of shaped rubber bands (8). On each beam (4) a rib (9) 6 mm (¼″) thick and 35 mm (1 ³/₈″) high is welded, at the top of which there is a rubber pipe with a joining piece (10) which seals hermetically the joints between two adjacent trapdoors. This arrangement makes them noise-tight. Between the square framework welded to the locomotive frame and the trapdoors in the floor there is therefore no metallic contact. The floating floor formed in this way is largely protected against the sonorous vibrations

of the solid parts. On the floor of the driving compartment, moreover, a rubber carpet is laid (11) 8 mm (5/16″) thick. The floor with this acoustic insulation is 132 mm (5 ¼″) thick.

The steps on each side of the driving compartment are also insulated from the part above the bogies by means of « Sillan » mattresses 35 or 70 mm (1 3/8″ or 2 ¾″) thick.

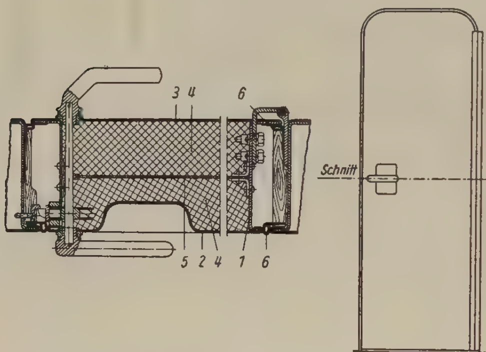

Fig. 21. — Swing door of machinery compartment; section at door knob level. Scale 1 : 5.

The driving compartment is separated from the machine compartment by a partition (fig. 20) with a swing door. On the framework of this partition which is made up of pressed sheet sections two layers of « Sillan » felt have been applied, one 90 mm (3 9/16″) (2), the other 40 mm (1 9/16″) thick (3) separated by a wall of 2 mm (5/64″) sheet (1). On the driving compartment side, the insulated partition, with a total thickness of 133.5 mm (5 ¼″) has been covered with perforated aluminium sheet (4) intended to absorb noise. The holes are 5 mm (3/16″) in diameter and represent 12 % of the total surface of the covering sheet. The walls behind the equipment cupboards and the driving table have been made in the same way. Here again the sides facing into the compartment have been covered with perforated aluminium sheet.

The swing door of the machinery compartment (fig. 21) is 130 mm (5 1/8″) thick. To make it as light as possible and easy to open, it has been made of light metal. The frame (1) consists of sheets of pressed aluminium alloy 3 mm thick. The covering sheets are 2 mm thick on the driving compartment side (2) and 1.5 mm thick on the machinery compartment side (3); the covering sheet facing the driving compartment is perforated. The space between the door frame and the covering sheets is filled in with two layers of « Sillan » felt plates 100

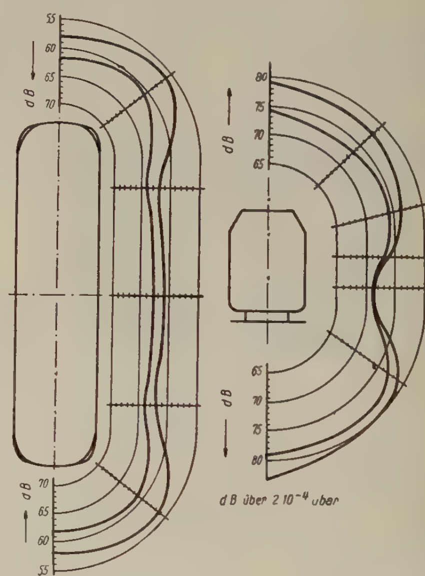

Fig. 22. — Exterior noises of the V 200 Diesel locomotive.

and 30 mm (4″ and 1 3/16″) thick respectively (4), separated by a sheet of wood fibreboard 3 mm thick (5). The edges of the door have been made tight all round by « Arabin » rubber piping with a rubber flange (6). The two side doors into the driving compartment have been given similar acoustic insulation and are fitted on the inside with perforated sheet.

Below the windows of the driving compartment, an insulating partition perpendicular to the longitudinal centre line of the vehicle has been fitted, which also is 130 mm thick, and similar in design to that of the partition between the driving compartment and the machine compartment.

The side walls of the locomotive are covered in with sheeting on the inside and outside with a gap of 70 mm (2 ¾″) between. The space is filled in with insulating mattresses made of « Gerriz » glass wool. In the machine compartment, the sheets are also perforated.

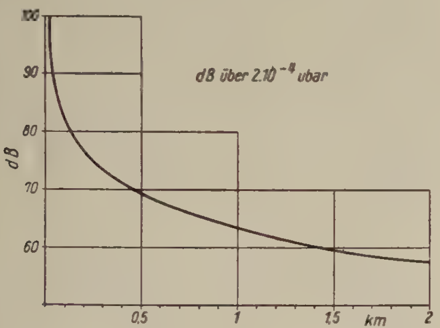

Fig. 23. — Sonorous intensity of the whistle of the V 200 Diesel locomotive.

The roof also consists of a framework and double covering of sheets, inside and outside. Here a 30 mm (1 $^{3}/_{16}$″) glass wool mattress has been put in the space. The trapdoor in the roof for withdrawing the hydraulic transmission consists of a 3 mm pressed sheet framework and an inner and outer covering of 2 mm thick aluminium sheet 60 mm (2 $^{3}/_{8}$″) apart, the space being filled with a « Sillan » mattress. The trapdoor closes hermetically against the roof by means of a rubber section, and the inner sheet is also made of perforated light metal. The trapdoors in the driving compartment roof are of similar design.

The windows in the front end of the driving compartment cannot be opened and are hermetically sealed by the frame sections. The windows in the entry doors also do not open. On both sides of the driving table, around the driver, are sliding windows, half of which can be opened up. Windows with double panes have not been used in the driving com-

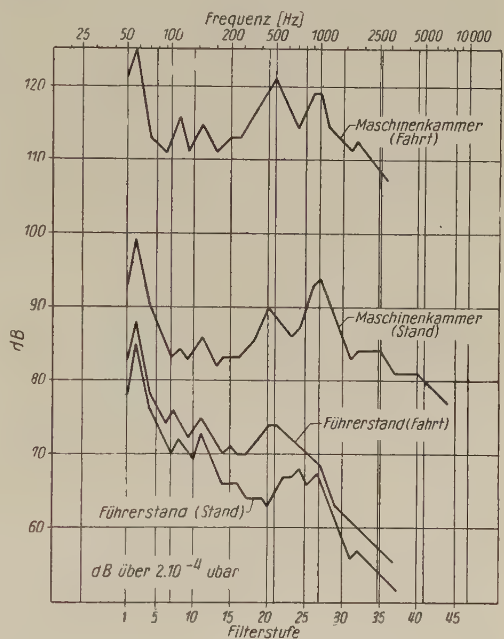

Fig. 24. — Analysis of the frequence of the sonorous vibrations of the air in the machinery compartment and driving compartment.

N. B. — Maschinenkammer = machinery compartment. — Führerstand = driving compartment. — Stand = at a standstill. — Fahrt = running.

partment although they would have given additional protection against noise, as experience of such windows is not yet sufficient. The importance of being able to see the signals and the track clearly led to the decision that it was not yet opportune to use double windows in the anti-noise campaign in this particular case.

Phonetic results of the anti-noise measures.

The Research Department of the Deutsche Bundesbahn carried out trials on a V 200 Diesel locomotive while stationary and while running, to ascertain the interior and exterior noises of the locomotives. Here again the levels of noise of the air vibrations were picked up at all the important parts of the locomotive by means of condenser microphones. The vibrations of the solid parts were measured by means of piezo-electric recording equipment. The running trials took place over the Departments trial section at a constant speed of 80 km (50 miles)/h.

Exterior noises.

Figure 22 shows the level of noise in the air on the outside of the Diesel locomotive, measured at ear level (about 1.80 m above ground level) and at a distance of 5 m (16′ 5″) and 10 m (32′ 9 3/4″) from the locomotive, as well as the level of noise around the section of the locomotives in planes CD and AB, measured at 1 m (3′ 3 3/8″) from the locomotive. The intensity of the noise, measured in decibels (dB) at ear level, varied between 56 and 65 decibels. It should be noted that there is a slight increase in the noise in front of the windows of the machinery compartment; this could probably be avoided if double windows were used. The increase in the level of noise under the locomotive is attributable to the numerous openings in the motor bogies.

Figure 23 shows the sonorous intensity of the locomotive whistle in terms of the distance. At 100 m (328′ 1″) the whistle is perceived with an intensity of 82 decibels. This shows that the exterior noises of the locomotive do not interfere in any way with the acoustic signals of the marshalling yard. The noise around the locomotive is in no way annoying for the public on the platforms.

Interior noises.

The interior noises were measured when at a standstill and during running at a speed of 80 km/h. The analyses of the

TABLE V. — **Differences of intensity of noise between the driving compartment and the machinery compartment on the V 200 Diesel locomotive.**

		Intensities in decibels at frequencies of :				
		55 Hz	250 Hz	500 Hz	750 Hz	1 000 Hz
At a standstill	Driving compartment	85	66	65	67	68
	Machinery compartment	99	83	89	89	94
	Difference	14	17	24	22	26
Running	Driving compartment	88	71	74	71	68
	Machinery compartment	125	113	121	115	119
	Difference	37	42	47	44	51

TABLE VI. — **Comparison of the noise intensities in the driving compartments of the V 200 Diesel locomotive and the series 50 steam locomotives.**

Type of locomotives	Noise intensities		
	Maxima values in phons	Averages in dB	
		Propagated in air dB_L	Propagated in solids dB_K
V 200 Diesel locomotive	86/87 phons	91.4	51.5
Series 50 steam locomotive	108/100 phons	105	53

frequencies of the sonorous vibrations are given in figure 24. Table V gives a comparison of the different intensities of noise between the machinery compartment and the driving compartment at different frequencies.

From these two figures, it will be seen that the interior noise of the locomotive is dominated by a low frequency of 55 Hz from the motor equipment. There was not found to be any difference in the noise when running due to the condition of the track. The differences in noise between the machinery compartment and the driving compartment are, whilst at a standstill, 14 decibels, but when running, on the contrary they amount to 37 decibels and are therefore quite appreciable. Thanks to the noise absorption measures taken, the high frequency components are the most strongly damped out. In the scale of sonorous frequencies, the good results of sound insulation are therefore clearly perceptible.

Comparison with steam and electric locomotives.

During the studies, it was found that the staff of the V 200 Diesel locomotive was exposed during running to an average level of noise due to air vibrations of 91.4 decibels, and to vibrations of 51.5 decibels (corresponding to an amplitude of acceleration of 0.32 g). According to Table VI, these intensities for the interior noises of the V 200 Diesel locomotive are appreciably lower than those of the series 50 steam locomotive. The series 01 steam locomotive of the Deutsche Bundesbahn, when running at 120 km (74.4 miles)/h has an interior noise level of 112 phons, when running over rails with undulatory wear, and 101 phons on rails without such wear. On the series 18 electric locomotive the interior noises at 90 km (55.8 miles)/h are 104 phons on rails with undulatory wear, and 98 phons on rails without such wear. There is a considerable difference in the intensity of the interior noises on these two locomotives according to the condition of the rails, which proves, that contrary to the case with the V 200 locomotive, the greater part of the noises consists of running noises. With these two types of locomotives, the interior noises are higher than on the V 200, in spite of the considerable noise due to the thermal engines. Because of the considerable reduction in the interior noises, work in the driving compartment of the Diesel locomotive which is spacious, protected from the weather, and heated, can be said to be perfectly pleasant.

[625 .215 (44)]

The development of bogies for railcars of the French National Railways,

by M. Tourneur,

Ingénieur en Chef, Chef de la Division des Études de Traction à Moteurs thermiques de la S. N. C. F.

(*Revue Générale des Chemins de fer*, November 1955).

Numerous improvements have been made in railcar bogies in order to achieve a degree of comfort in service comparable with that of passenger coaches. The following article is designed to describe the development of S. N. C. F. railcar bogies during the past twenty years.

The production of railcar bogies presents greater difficulties than with carriage bogies for the following reasons :

— because of the relatively limited power of Diesel-engined railcars, the need for weight reduction is more marked than with ordinary stock. Moreover, it is well-known that it is more difficult to obtain a satisfactory degree of comfort with a light vehicle than with a heavy one; in addition, the weight reduction is applied more to the body than to the bogies, so that, in general, the ratio between bogie weight and load carried is greater on railcars than on coaches; this feature is particularly accentuated on railcars where the motor and transmission are mounted in the bogies;

— as the axle loads of railcar trains are lower than those of trains hauled by locomotives, and as the centre of gravity of the vehicles is relatively low, railcars, generally operate, on any given stretch of line, at a higher speed than trains. They therefore often work over curves having insufficient superelevation which tends to accentuate the undesirable effects of variation in curvature, on the stability of the vehicle;

— railcars are required to work singly, so that there can be no reliance on the presence of trailing vehicles to deaden transverse movement of the body;

— finally, with mechanical and hydraulic transmissions, the presence of components transmitting power to the axles gives rise, in the design of the bogie, to restrictions which are sometimes considerable.

The bogies of railcars, which were originally inspired directly by carriage bogies, have undergone considerable development and we propose to give a survey of what has been done on railcars of the French Railways.

After several observations on the general structure of railcar bogies, it has seemed to us desirable, for clarity, to examine successively the following three groups of component parts : connections between bogies and body; those between bogies and axles, and finally brakes.

We have set out in the following table (page 931), the essential characteristics of the bogies mentioned in the following notes.

A. — GENERAL DESIGN OF RAILCAR BOGIES.

With regard to the location of motor equipment, two ideas have been widely tried in France before 1940 : Diesel motors and transmission mounted on the bogie or in the body.

The main advantage claimed for mounting on the bogie rests in the possibility

Date in ser-vice	Type of railcar	Driving or carrying bogie	Wheel base	Wheel dia-meter	* P′ Load on the pivot		P Weight of complete bogie	Ratio P′/P	Height of pivot above plane of axles	Spacing of body bearings or second-ary suspension springs	Spacing of primary suspension springs	Flexibility per bogie ton of the springs: Primary suspension		Secondary suspension	
				mm	the pivot kg	the two side bearings kg	kg		mm	mm	mm	laminated	helical	laminated	helical
1933	Renault 300 HP VH	M	2.2	860	11 700	2 600	4 700	3.04	450	1 500	1 856	5.5	1.8		
		P		860	10 000	2 600	4 000	3.15	490	1 500	1 856	5.5	1.8		
1948	Renault 300 HP AB 14	M	2.5	860	11 200	6 000	4 700	3.66	450	1 500	1 856	5.5	1.8		
		P		860	7 100	6 000	4 000	3.28	490	1 500	1 856	5.5	1.8		
1936	Renault 300 HP AEK	M	2.7	860		15 000	4 000	3.75	160	1 040	1 750	12.0			
1936	Standard	M	3.3	860		15 000	12 000	1.25	50	1 950	1 890	1.2		6.65	
1936	T A R 2nd series	Bogie generat.	3.5	970	16 000		11 500	1.33	610	2 110	2 000	1.6	2.6	7.4	
1935	Dietrich 320 HP	M	3.5	860	15 500		7 250	2.14	605	1 990	1 880	2.5		8.5	
1936	Bugatti, extended	M	2.7	720	18 500		3 500	5.30	200	2 000	1 160	2.87			4.12
1936	Lorraine	M	3.5	860		11 200	5 500	1.85	150	1 920	1 920	1.0		11.3	
1936	Decauville 1st series	M	2.8	900	14 475	2 000	10 000	1.64	500	1 380	1 080	6.4			
1945	Decauville 2nd series	M	2.8	900	12 450	5 800	5 750	3.18	370	1 460	1 100	4.0			2.92
1952	SNCF 300 HP	M	2.6	860		18 340	5 160	3.56	160	1 700	1 140		2.21		7.52
		P	2.6	860		11 900	4 250	2.80	160	1 700	1 140		2.21		9.90
1951	SNCF 600 HP	M	3	860		20 660	5 200	3.98	165	1 600	1 140		1.70	5.75 3.25	2.5
1954	Long distance train sets: Single-motor car	M	2.85	900		27 000	7 000	3.75	0	1 700	1 100		1.63		5.13
		P	2.6	860		15 500	4 250	3.65	165	1 700	1 140		2.21		9.26
1955	Long distance train sets: Trailer	P	2.5	860		15 000	3 600	4.16	0	1 700	1 100		2.9		10.4

Note — * The loads shown are based on the full normal load.

of being able, during maintenance, easily and quickly replace a complete motor equipment by another by simply changing the bogies; in addition, it may be considered that the absence of motive parts in the body tends to improve the degree of passenger comfort. On the other hand, the presence of motor equipment on the bogie increases the weight of the latter, particularly when the power is fairly high, which is not good for the track. Finally, some difficulties result from provision of flexible leads between the body and the bogie for air, water, and fuel supplies and from the need to provide access from inside the body to various parts mounted on the bogie.

It is also necessary to mention the progress realised in the construction of Diesel motors and transmissions which have been the means of considerably increasing the mileages between overhauls to the extent that these are now much greater than the mileages obtained from the running components. This means that the result of arranging maintenance by exchanging complete bogies increases the stock of spare bogies and transmissions, that is to say, the most costly parts. Finally, experience has shown that suitable mounting of the Diesel motors in the bodies can obviate the transmission of vibrations from the motors to the passenger compartments.

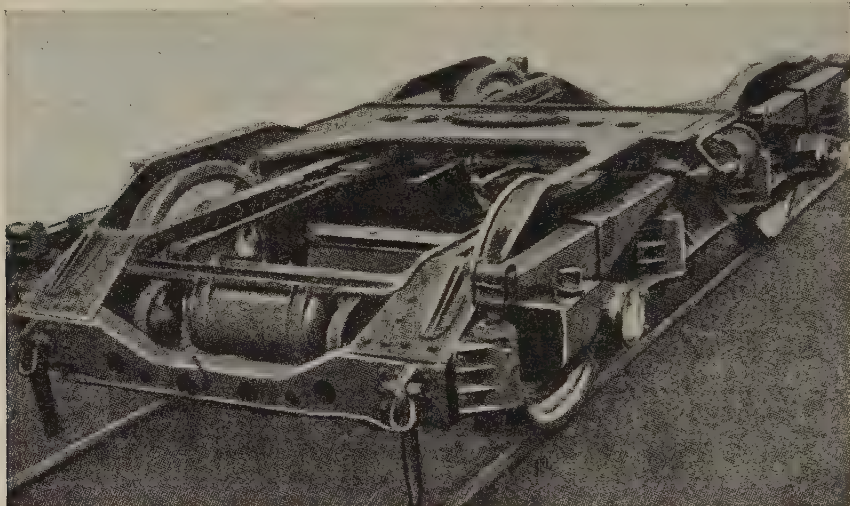

Fig. 1. — Carrying bogie of Renault railcar VH type (1933).
Axleboxes with slides, primary suspension by laminaned springs, pivot without possible transverse movement.

On railcars of standard types built since 1948, the S. N. C. F. has therefore given up the location of the motor and transmission on the bogies.

For reasons of weight, bogie frames have from the start been built of welded plate, certain manufacturers having at the same time made use in the early stages of mixed rivetted and welded construction. Modern bogies, generally, comprise box girders formed as simply as possible and designed to provide maximum rigidity. We will not dwell on the technique of frame production, which is the same as

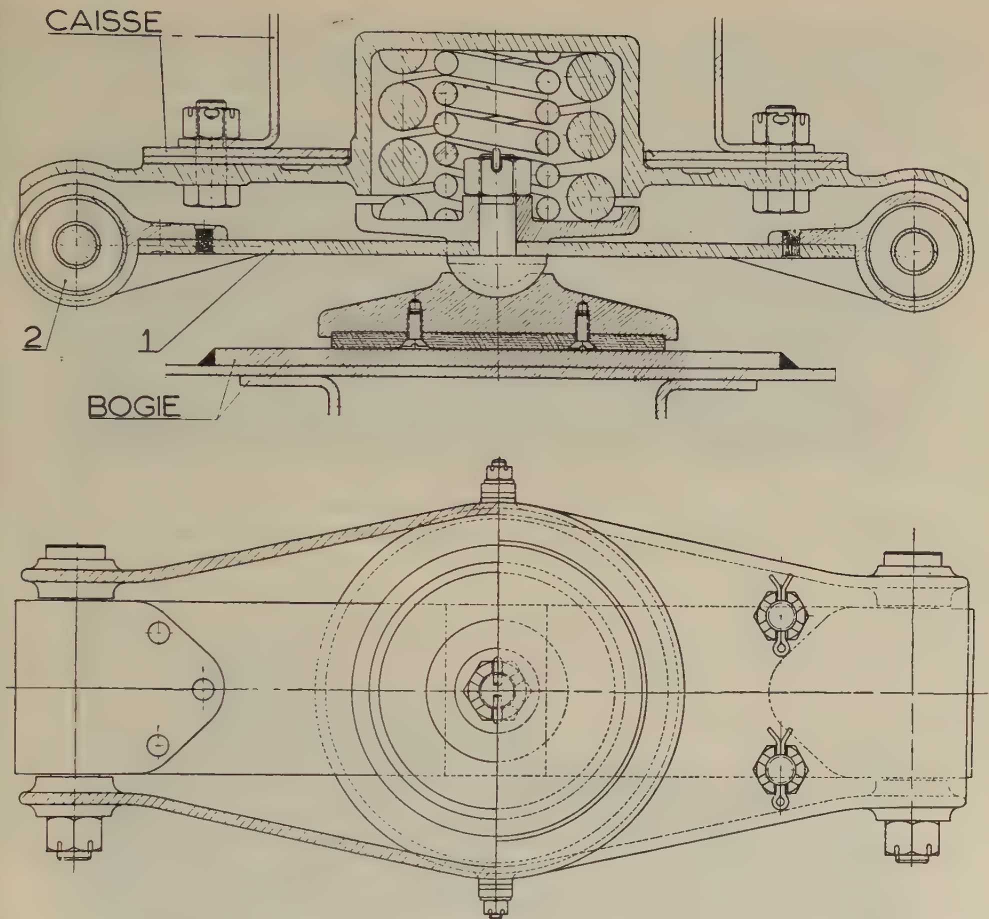

Fig. 2. — Body side bearing of Renault railcars, type ABJ4 (1948).

Axleboxes with slides, primary suspension by laminated springs, pivot with no possible transverse movement. The elevation shown is perpendicular to the axle.

1. — *Flexible plate.*

2. — *Silent bloc.*

Friction surfaces : asbestos on steel, not lubricated.

that for carriage bogies, but is sometimes complicated by the presence of motor units.

On most bogies built before 1940, the axles were of the normal types, with external axleboxes; at the same time, Decauville railcars in particular have since 1935 been fitted with inside axleboxes. This arrangement is better for inspection and maintenance of brake rigging and blocks; it increases the periodicity of body-roll which is to the benefit of the track.

On these railcars the wheels, which are monobloc as on the great majority of French railcars, are pressed on to conical

Fig. 3. — Driving bogie of express railcar, type TAR (Franco-Belge, 1934).
Secondary suspension by laminated springs. No transverse displacement of the pivot.

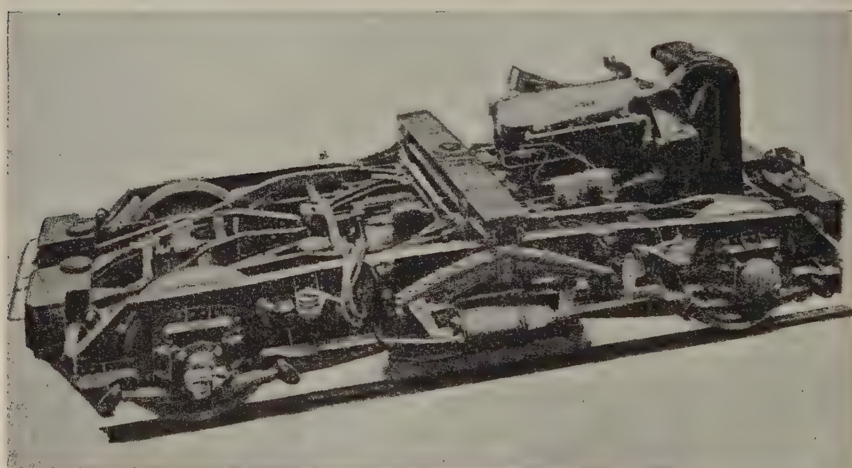

Fig. 4. — Driving bogie of de Dietrich railcars 2 × 160 HP (1935).
Secondary suspension by laminated springs with swing links allowing transverse displacement of the pivot.

seats, which facilitates inspection of the axles during workshop overhaul and allows easy dismantling of the roller bearing axleboxes.

Because of the advantages which have just been mentioned, the bogies of standard S. N. C. F. railcars built since 1948 have the following features : inside axleboxes and conical wheel seats.

The bogie frame of these railcars and

of some recent trailer vehicles, comprises in essence two solebars of 5 mm (3/16″) plate, in box-girder form, and two central cross-members whose extremities receive the bearing springs of the secondary suspension rods, as can be seen later (fig. 6, 7 and 10).

B. — CONNECTIONS BETWEEN BODIES AND BOGIES.

The first railcars, the maximum speed of which was little more than 100 km (62 miles)/h had bogies which were relatively simple and of normal type, with a spherical pivot and side bearings each supporting about 12 % of the pivot load. By careful regard for weight and simplicity, no secondary suspension or swing bolster are provided. The bogies of the first Renault railcars with Diesel motors, for example (1933), come into this category (fig. 1).

As the body cannot take any relative transverse movement in relation to the bogie, the hunting movement of the latter, which can become noticeable above about 80 km (50 miles)/h particularly when the axlebox slides are well worn, is appreciable (2 to 3 mm), and is transmitted to the body, to the detriment of comfort.

From 1935, on this class of railcar, an improvement has been obtained by increasing the load on the side bearings (40 % of the total load on the bogie) and by replacing the bronze/steel lubricated rubbing surfaces by a non-lubricated asbestos/steel combination. However, because of the low relative displacement of the rubbing plates, it appeared necessary to avoid the possibility that horizontal play, even very slight, might occur in the flexible links connecting the upper rubbing plates and the body (fig. 2).

As a result of increased speed, it became necessary to provide a secondary suspension. On railcars of the Franco-Belge and de Dietrich types, the pivot, which carries the whole weight (Franco-Belge) or the greater part (de Dietrich) of the body has been retained and this is carried by a cross-bearer supported by two large laminated side bearing springs; the cross-bearer moves in slides taking either longitudinal or transverse efforts (TAR bogies, 1934 type, fig. 3) in which case the pivot is allowed no transverse movement relative to the frame, or taking longitudinal stresses only (TAR bogies, 1936 type, de Dietrich bogies, fig. 4), the ends of the laminated springs then being carried by hangers allowing transverse displacement (± 15 mm [± 5/8″]). The side bearings of the de Dietrich bogies resting on the cross-bearer transmit a part of the weight of the body and damp any hunting movement.

A similar arrangement was used on railcars built by the « Aciéries du Nord » (1935) but on these the pivot does not tranfer the vertical load, which is taken directly on to the side bearings (steel rubbing on steel, with lubrication). The cross-bearer, which is subject to lower stresses, is easier to design on bogies which have to accommodate the driving equipment. On the other hand, with such bogies, the frictional torque due to the transomes is often unfavourable as regards flange wear, even on lines with few curves.

On the bogies of railcars built in 1936 by the Lorraine de Luneville Company (fig. 5) the pivot does not transmit any vertical load and the hanger links of the two large laminated side bearing springs of the secondary suspension take the load of the body through a lubricated rubbing plate provided with a vertical pin which allows the spring to pivot on it; the weight is then transmitted from the spring to the bogie frame by two long suspension bars on ball joints. This arrangement allows transverse displacement of the body in relation to the bogie, and the angle taken by the rods then engenders a recoil force to the rotational movement of the bogie and a transverse recoil bogie effort.

The large laminated secondary suspension springs have the disadvantage of being much too heavily damped, particularly on heavy railcars because of the size and number of the laminations. Since 1938, the Decauville Company on railcars ordered by the former P. L. M. have used helical springs in combination with hydraulic shock-absorbers. On railcars with electric transmission, it has been possible to use the normal swing bolster with side recoil by hanger links, also in combination with a hydraulic shock absorber.

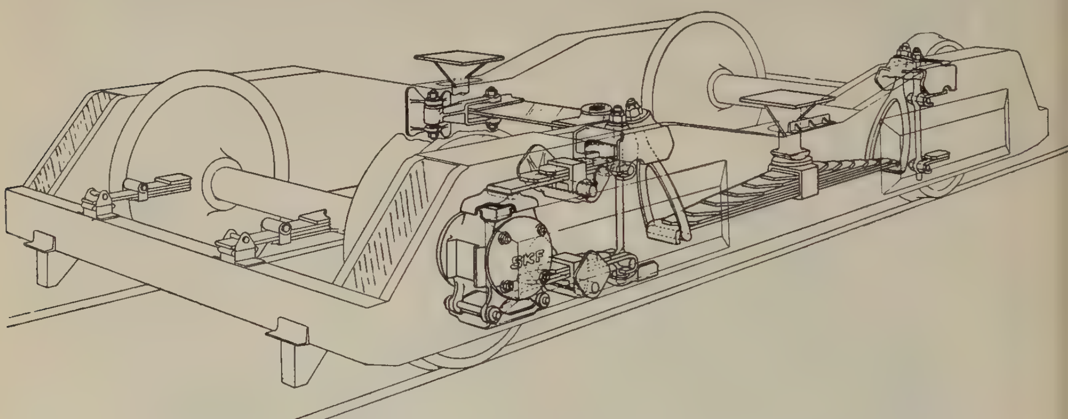

Fig. 5. — Diagrammatic sketch showing in perspective the suspension of the LORRAINE (1936) railcars.

Bogies of 300 and 600 HP S.N.C.F. railcars.

When in 1944, the S. N. C. F. undertook the design of a standard type of railcar, the new bogies were established on the basis of experience acquired with the types described above, and with the prototype bogies tried in 1943; it was decided to retain the following fundamental arrangements :

— abandonment of pivots transmitting all or part of the vertical load of the body, so as to reduce the weight of the pivot beams and the space required in the central part of the bogie. On the 600 HP bi-motored railcars (fig. 6), the pivot mounted on the body, is connected to two adjacent cross-members of the bogie by two rods with « silentbloc » mountings, which transmit the longitudinal traction and brake efforts, whose axes are horizontal, to allow the vertical movement of the body which, because of the variations in pay-load of railcars, may be as much as 70 mm (2 ¾″). The resilience of the rubber in the « silentblocs » allows transverse movement of the body without exercising any appreciable recoil force (140 kg at a displacement of 15 mm).

On the 300 HP railcars, with mechanical transmission which, mounted in the body, fouls the centre of the bogie, it was not possible to use a pivot; this has therefore been omitted and longitudinal forces between body and bogie are transmitted by two cables fixed to the body near the bogie centre and connected to two equalisers fastened to the bogie headstocks (fig. 7). This arrangement, which is easy to produce, is very satisfactory in

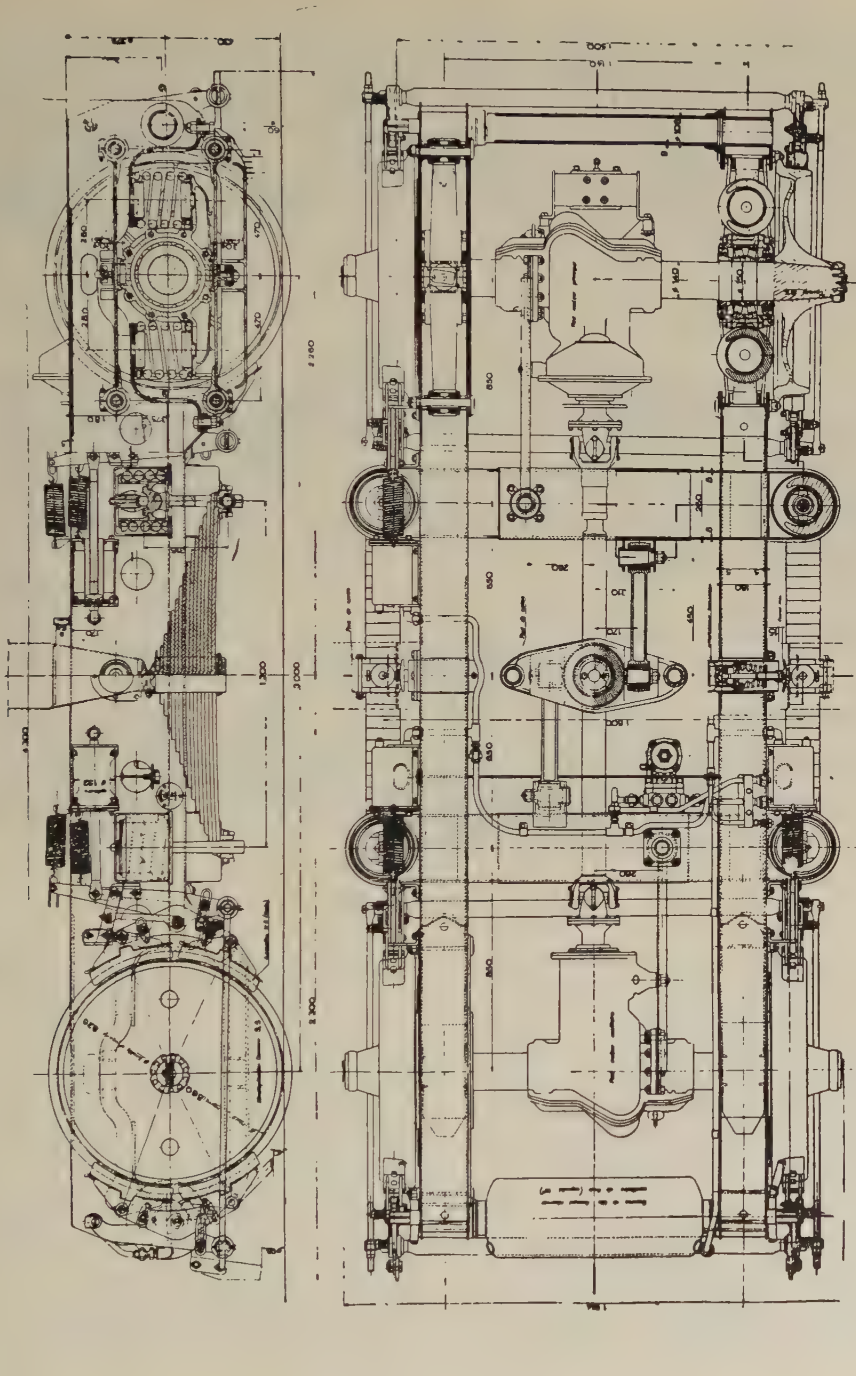

Fig. 6. — Driving bogie of 2 × 300 HP railcars. S. N. C. F. type, 1st series, (1951).

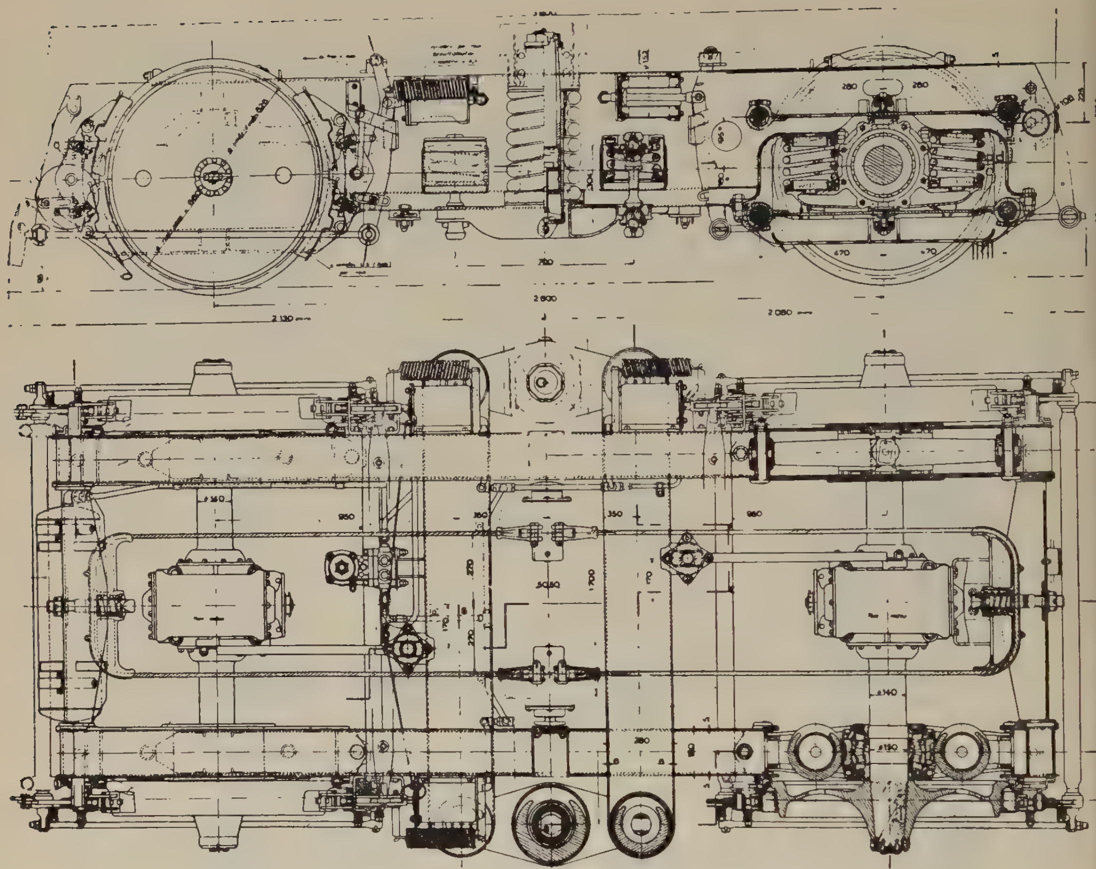

Fig. 7. — Driving bogie of 300 HP railcars, S. N. C. F. type (1952).

service and allows the bogies great freedom of movement;

— the secondary suspension comprises two groups of helical springs, arranged laterally, which support the full weight of the body (fig. 7). Experience had shown the necessity of permitting a certain degree of displacement of the body transversely in relation to the bogie to ensure good running at high speeds and it had also been acknoledged that the recoil force for these movements must be moderate at low amounts of displacement. This dual requirement is difficult to fulfil when the swing bolster is omitted and the friction rubbing blocks are retained to allow rotation of the bogie. Use has therefore been made of the arrangement which was found satisfactory on the Lorraine railcars and which, it may be recalled, comprises a connection from the secondary suspension to the bogies by ball-jointed links which can move in all directions. The universal joints are in this case formed by a ball inserted between two steel bushes.

On the first 600 HP railcars which were built, the laminated springs of the second-

ary suspension were retained (fig. 6), but the yoke is made solid with the body so that, on a curve, the springs remain parallel to the longitudinal plane of symmetry of the body which increases the rotational recoil torque. Because of their inadequate sensitivity these springs have been replaced on subsequent series by helical springs, with relatively high flexibility, combined with a hydraulic shock absorber mounted inside the spring. With this arrangement it has been possible to shorten the bogies and the minimum acceptable radius of curvature has been reduced.

those needed for the speeds of operation of railcars, it has been considered necessary to increase the possible transverse displacement between body and bogie by a considerable increase, by springs, of the recoil effort at high amplitudes and a reinforced shock absorber action. For example, in the case of fast railcars with trailing coaches for long distance feeder service, where the empty weight of the trailer is comparable to that of a modern carriage (32.5 t) the total recoil, due to the combined action of the « silentblocs » of the pivot, angle of the hanger links and the springs, which is nil at the start, reaches (taking into account the action of the hydraulic dampers) 685 kg for a transverse displacement of 10 mm, 1 835 kg for a transverse displacement of 20 mm, and 3 850 kg for a transverse displacement of 30 mm. Such an adjustment, which gives complete satisfaction at high speeds on good track, suppresses shock over rail joints, and the transverse oscillations set up when running through curves with a considerable inadequacy of superelevation.

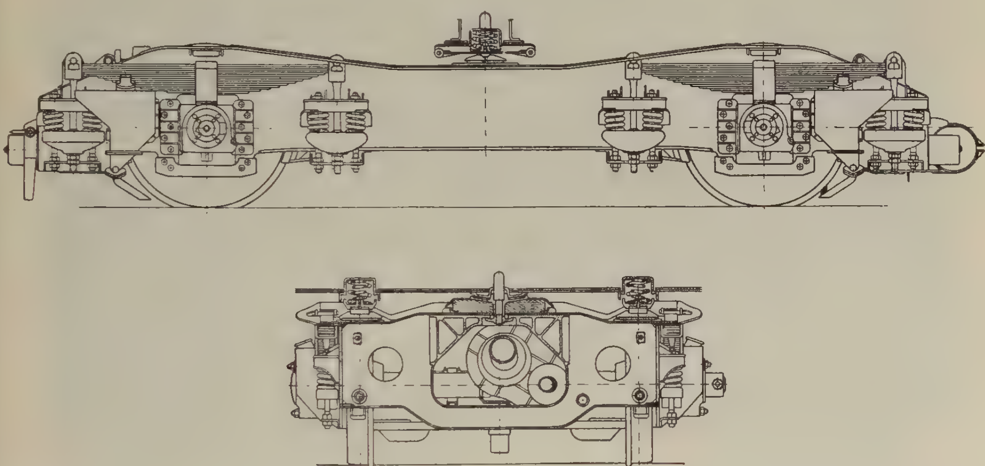

Fig. 8. — Suspension of Renault 2 × 300 HP railcars, type ADX (1939).
Primary suspension by laminated springs, combined with grouped helical springs.

In the S. N. C. F. 300 and 600 HP railcars, horizontal hydraulic shock absorbers control the transverse displacement of the body in relation to the bogies and vertical spring suspension bars develop no initial recoil. This arrangement has given good results on main lines, even at high speeds.

On the other hand, when running on secondary lines with numerous curves, which as already mentioned very often have considerable variations of curvature with degrees of superelevation lower than

C. — CONNECTIONS BETWEEN AXLES AND BOGIE FRAME.

The first railcars in service on the former railway companies' systems had normal type axleboxes with roller bearings, steel slides, generally bronze liners and laminated bearing springs. This arrangement, which was acceptable at moderate speeds, was rapidly found to be insufficient for stock exceeding 90 km (56 miles)/h because of the very undesirable influence, on the condition of the track, of the play set up between the slides and liners. In 1937, considerable improvement was obtained on certain railcars by using slides and liners of manganese steel which are much more wear-resistant.

The unresponsiveness of laminated springs has been counterbalanced on certain stock by the addition of helical springs (fig. 8). Certain builders (Berliet in particular) in 1935, even used helical springs only for the primary suspension, thus improving the standard of comfort.

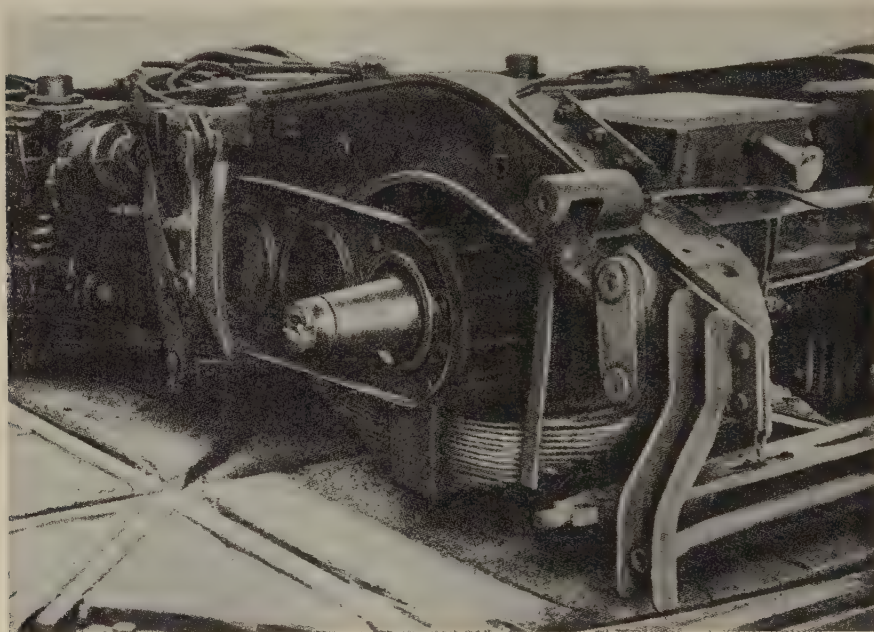

Fig. 9. — Part view of driving bogie of Decauville 2 × 300 HP railcars, 2nd series (1945).

Primary suspension by laminated springs, with connecting plates, hinged on « silentblocs » between axleboxes and bogie frame. Secondary suspension by swing bolster and helical springs in conjunction with vertical and transverse hydraulic shock absorbers.

Moreover, with a view to reducing the weight of the stock and simplifying manufacture, railcar constructors also adopted (Renault railcars, AEK type of 1939) a primary suspension based on road vehicle design, comprising a laminated spring fixed, on the one hand, under the axlebox by the buckle and, on the other hand, by a pin and bush transmitting horizontal forces between axles and bogie whilst allowing the spring free play. On

comparatively light stock, this arrangement gave satisfaction but is was necessary to retain the laminated spring with all its imperfections. Boxes without slides, combined with laminated springs, were also fitted to railcars of Decauville construction with a relatively high axle load (12.75 t); longitudinal tractive and brake efforts are in this case transmitted to the bogie axle by articulated side brackets on the bogie (fig. 9); transverse efforts continue to be transmitted by laminated springs.

S. N. C. F. type railcars built since 1948 have a primary suspension made up solely of helical springs in pairs on each side of the axlebox. To ensure strict parallelism of the axles irrespective of wear, the linkage between boxes and bogie is provided by two flexible steel plates fixed at the centre to the axlebox (fig. 6 and 7) and connected at their ends to the bogie frame by rubber inserts which absorb slightly the lateral blows of the flanges on the rails and also allow variations in deflection of the plates for vertical displacement of the boxes; these plates have practically no part in the suspension of the bogie.

So far it has not appeared necessary to add shock absorbers to this primary suspension, the pitching movement of the bogie remaining within acceptable limits. However, the measures taken in this respect have shown the necessity for arranging the pivot of the bogie on the centre of the plane of the axles. If this condition is not fulfilled, bogie oscillations, even of a moderate nature, will set up in the pivot alternating longitudinal forces which can, because of the relative lightness of the bodies, give rise to disagreeable vibrations particularly when bogie movements are in opposing phases. This phenomenon is moreover very noticeable in some older railcars with heavy bogies and pivots not reduced in height.

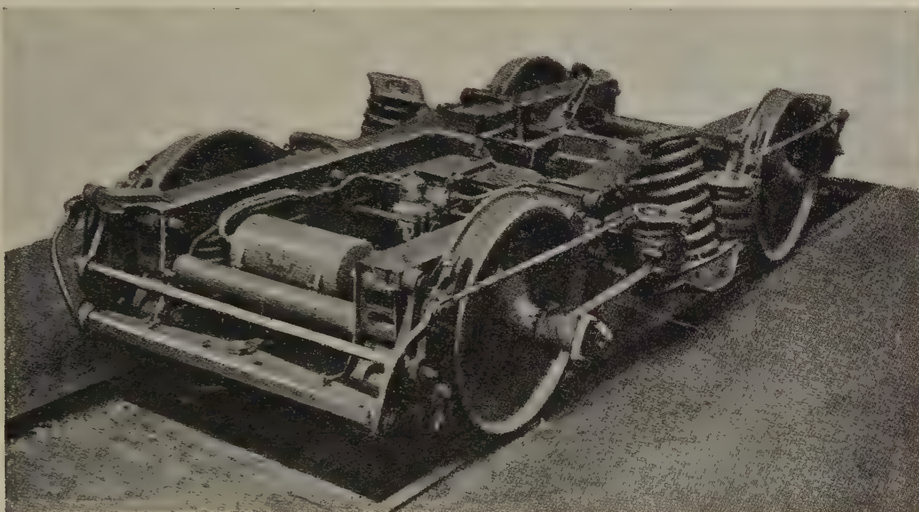

Fig. 10. — Trailer bogie for long distance railcar sets (1955).
Primary and secondary suspensions by helical springs, with vertical and transverse hydraulic shock absorbers on the secondary suspension; inside axleboxes without slides; pivot carrying no vertical load; side bearings without rubbing surfaces.

D. — BRAKES.

The French Railways have tried numerous brakes, both shoe and drum types; the latter have shown themselves to be difficult to maintain when worn because of the impossibility of allowing sufficient size for the brake linings and also it is equally obvious that the absence of brake shoes mitigates against the efficient operation of some track circuits as the cleaning action on the wheel flanges is less. The shoe type brake has therefore been retained on the S. N. C. F. type railcars but each wheel is braked by four shoes to reduce the specific pressure and to increase very considerably the life obtained from the shoes before they are worn out.

* * *

In brief, the bogies of the most modern French railcars have the following features :

— welded frame of steel plate; inside roller bearing axleboxes; monobloc wheels with conical seats;

— primary suspension by helical springs; axleboxes without slides, eliminating any longitudinal or transverse play;

— bogie pivots in the axle plane, carrying no vertical load;

— secondary suspension by helical springs only, with hydraulic shock absorbers;

— transverse displacement of the body controlled by secondary suspension links, springs and hydraulic shock absorbers;

— bogie centring by angularity of secondary suspension hanger links;

— complete absence of friction from rubbing surfaces in suspension and pivots;

— shoe type brake with four shoes per wheel and rigging outside the solebars.

Experience shows that such bogies provide a particularly smooth vertical suspension and, transversely, ensure a stability comparable to that of the best carriages, even when operating as a single railcar.

[621 .33]

The economic value of railway electrifications,

by Ernst Ludwig, Dipl. Eng., Erlangen.

Shortened version of a lecture given to the German Railway Engineers Association at the Hanover Technical Fair.

(*Der Eisenbahn Ingenieur*, October 1955).

Amongst the operating methods which can be considered for a railway, electric traction undoubtely is now specially favoured. Most often, the electrification of railway lines is considered as an important step forward in itself. The increased acceleration and high speeds of the electric locomotives and railcars are boasted of as shortening the journey times very considerably; mention is made of other agreeable features of electric traction, its cleanliness, its advantages from the point of view of the suppression of noise, smell and vibrations. And yet these are only the external advantages. Those who use the railway profit from them and they have great publicity value. But this does not give any idea of the profitability of electric traction. To learn how to recognise the scope as well as the limits of the economic advantages of electric traction for the railway, is the object of our considerations.

Influence of the method of utilisation of natural power on the economic efficiency of railway operating.

We will show first of all in figure 1 how the principle of electric traction fits in with the different possibilities of mechanical drive for land transport. This will already show as a first approximation under what conditions electrifying a railway can prove economic.

In the method of using the natural or crude power, two systems have been proved in practice :

I. *Storing the power on the vehicles.*

The stored power carried on the motor vehicles can be the natural power itself (I*a*) or forms of power derived from the natural power (I*b*). For these two possibilities, we have given in figure 1 the best known examples of application : in the first column for railway vehicles, in the second for vehicles other than those running on a railway line.

II. *Supplying power to the vehicles.*

In this second system, the power is supplied to the vehicles all the way along the line. The natural power is then transformed in the fixed installations, either into electric power (II*a*) or into mechanical power (II*b*). The line has to be equipped with an electric or mechanical transmission line (fixed contact line or moving traction cable).

Controversy on the respective advantages of the two systems, storing or supplying the power, had already started at the beginning of the last century when the railways in England were in the preliminary stages of their development. Soon however, in spite of the advantages of having a single fixed power house, which, considered as a unit by itself, could work much more economically than a large number of small mobile engines, it was the latter solution which triumphed in the form of the steam locomotive.

The difficulties of supplying power to vehicles could not be overcome until in 1879, Werner von Siemens, thanks to the

invention of the electric locomotive, succeeded in « drawing » vehicles by means of fixed machinery, no longer mechanically by means of a moving cable but electrically by means of a fixed contact wire or third rail.

Owing to the invention of electric railways, the system of supplying power to vehicles again became of great importance, and the two systems are in strong competition against each other at the present time. On the railway, the steam locomotive and Diesel units are the chief examples of the first system, and electric motor units of the second.

As regards the question of the system which in the present state of technique should be considered the most advantageous, this can be solved in principle without any thorough-going economic calculations.

The profitability of any technical investment is a function of its degree of user. For example it has become necessary to close down a certain number of secondary railway lines with little traffic because the services in these cases could be more economically run by motor omnibuses.

Any equipping of a railway line with installations to supply current to vehicles the whole way along the line is a new capital investment which must be added to the existing installations. On electric railways, the profitability of the working depends therefore, even more than on railway lines without a power supply, on the actual daily user of the fixed installations by a sufficiently large number of vehicles.

This brings us to the statement that electric traction is economic on lines with heavy traffic; steam or Diesel units can be used on lines with small or moderate traffic.

A few more words on the other categories of vehicles included in figure 1 :

The steam turbine locomotive and the gas turbine locomotive have not come into general use to date, and there is nothing to lead us to expect any alteration in this position. However, in recent years, a few experimental gas turbine locomotives have been put on trial. But owing to its poor efficiency under part load and when running light, the gas turbine is still provisionally unlikely to be used for traction on the railways.

The power units of category I *b* on which is stored not natural power but some other form of power produced from natural power which is transformed upon the vehicle into mechanical power, have various advantages such as : elimination of fire risks, of smell, noise and vibrations. However, their radius of action for each charge of the accumulators is smaller than that of vehicles using natural power directly. On the railways, vehicles of this type are only therefore likely to be used for special objectives. However, the electric accumulator railcar is becoming more and more important in railway operating. These vehicles are now able to travel 300 km (186 miles) on one battery charge.

In the group of vehicles with an outside source of power, besides electric traction, vehicles with a supply of mechanical power (II *b*) continue to be used in their own special fields. A low speed, a particularly heavy traffic consisting of an uninterrupted succession of small single vehicles, a short line, steep gradients so that it is necessary to be independent of the adhesion between the wheel and the rail, these are the characteristics of certain problems which can often only be solved by supplying mechanical power, both from the technical and economic points of view (for example : mountain railways and goods transport installations).

Amongst vehicles, the trolleybus occupies a special place. It requires a supply of power all along its route, but it is independent of a network of rails. In the case of a trolleybus undertaking, it therefore costs less to equip the line than in the case of a tramway, but more than for a Diesel bus service. Short distance traffic furnishes another particularly clear example of the relationship between « cost of equipping a line » and the « amount of traffic ». If we recall the influence of the degree of user of the fixed installations on operating economy, we can see that the field of application of a tramway is that of very heavy traffic with very frequent vehicles, whilst that of the trolleybus is that with an average amount of traffic, and that of the Diesel bus service a small amount of traffic with long intervals between buses.

<table>
<tr><th colspan="3"></th><th>Railway vehicles</th><th>Vehicles running other than on railway lines</th></tr>
<tr><td rowspan="4">Natural power : coal, petrol, gas, hydraulic power, atomic power</td><td rowspan="2">I. The stored power is transported all along the line on the vehicles</td><td>Transport of : a) stores of natural power</td><td>Piston steam locomotives
Steam turbine locomotives
Gas turbine locomotives
Diesel locomotives
Diesel railcars</td><td>Motor cars with petrol or Diesel engines</td></tr>
<tr><td>b) stores of other forms of power</td><td>Piston steam locomotives without firebox, using compressed air, using accumulators
Rail motor coaches with accumulators
« Gyro » system railcars</td><td>Accumulator motorcars

Gyrobus electric cars</td></tr>
<tr><td rowspan="2">II. The power is supplied to the vehicles all along the line</td><td>a) Supply of electric power</td><td>Locomotives and railcars using the contact line
Tramways, suspension railways, etc.</td><td>Trolleybuses</td></tr>
<tr><td>b) Supply of mechanical power</td><td>Funiculars, telpher railways, conveyor belts, etc.</td><td></td></tr>
</table>

Fig. 1. — Distribution of overland transport according to the kind and place of the conversion of natural power used for the mechanical traction power.

More accurate calculations of the profitability.

In the general economy, there are a whole series of other cost factors — in particular the cost of buying the vehicles, and the cost of power. Most Railway Administrations throughout the world whose financial position is menaced by the competition of the motor and the

aeroplane, now have to face the question of deciding to what extent the profitability of their undertaking could be increased by adopting some other method of traction. It is a question of deciding whether the old method of traction by steam locomotive should be replaced by electric traction or by Diesel locomotives. In order to reach a decision, it is necessary to make accurate calculations of the total traction costs for the different methods of operating. In Germany, very thorough-going studies have been made in recent years by the « Arbeitsgemeinschaft Dieselschienenverkehr » (Diesel traction on rail Commission). In the figures which will be quoted in our report, we have used to some extent the results of the calculations made by this commission [1].

The traction costs for steam, electric or Diesel engines consist in each case of :

1) the capital cost of the motor units;

2) the maintenance costs for the motor units;

3) the cost of personnel for the engines, and

4) the cost of power.

In order to facilitate the comparison between the two types of traction with power stored on the vehicles (steam and Diesel locomotive) and the type of traction with power supplied to the vehicle (electric locomotives), it is necessary, in the case of electric traction, to include in the cost of the power all the costs involved in supplying the power. The basis is therefore the cost per kWh of electric power at the pantograph of the electric locomotive in which is included not only the *loss of current* in the transmission from the power station to the pantograph but also all the *costs* of this transmission, in other words the capital costs, maintenance and personnel costs for the power stations, lines for transporting the current, sub-stations and contact lines. This is of particular importance for understanding the comparison and the conclusions to be drawn from it.

Figure 2 shows the costs which now relate to each of the four factors and for their total. In comparing the cost of traction per locomotive-km with the three methods of traction, we have taken into account an express train with a trailing load of 330 t, a freight train with 875 t, and a stopping train of 150 t. As the definitions of the power of the locomotive vary for the three methods of traction, in the comparative calculations we have used types of electric and Diesel locomotives which are capable of carrying out a similar running programme to the types of steam locomotives used for the loads selected. In view of their greater availability, the electric and Diesel locomotives have been credited with a rather higher daily mileage than the steam locomotive.

Starting from these hypotheses, the comparison gives the following results :

Capital costs for the motor units.

The electric locomotive costs about 1.4 to 1.6 times more than the steam locomotive. The Diesel locomotive (taken as having hydraulic transmission) is about 2.3 to 2.5 times more costly than the steam locomotive. From the point of view of purchase price, steam traction is therefore the cheapest.

By using the purchase prices of the motor units, the amount required for the capital fund (interest and sinking fund) have been calculated.

Maintenance costs for the motor units.

The costs include the cost of small repairs, overhauls, lubricating oil, etc. In the case of the electric locomotive, they amount to about 30 to 40 % of the corresponding costs for the steam locomotive; for the Diesel locomotive, to 50 to 70 % approximately.

Personnel costs for the motor units.

The steam locomotive has to be manned by a driver and a fireman. On the electric and

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[1] « Dieselfahrzeuge im Schienenverkehr » (Diesel vehicles in railway traffic). Carl Röhrig, Publisher.

Diesel locomotives, there is no need for a second man. Only one driver is needed. In addition with these locomotives, the time needed for lighting up and getting up steam in the case of the steam locomotive is also saved. For all these reasons, the personnel costs for the electric locomotive and Diesel locomotive have been put at 45 % of those for the steam locomotive.

Cost of power.

The most important group of costs is that due to power costs. In our comparison, we have taken as a basis, as regards the power concerned, the 1950 prices, which are, for coal 48 D.M./t, for Diesel oil 355 D.M./t. The cost of electric power was calculated as 0.06 D.M./kWh.

The cost of power per locomotive/km obtained with these prices, for the hypothetical operating conditions, amounted to 60 to 80 % of those of the steam locomotive in the case of the electric locomotive and on the average some 90 % for the Diesel locomotive. Under the heading of power costs, which represent about half the total traction costs, the steam locomotives are therefore the most costly. This result is indisputably due to the fact that on the steam locomotive the raw material coal is necessarily poorly used. The total efficiency, which expresses the ratio between the mechanical power used at the tread of the driving wheel to the power contained in the fuel in the case of the steam locomotive only amounts to 10 to 11 % at the most in round figures. The annual output, which is of capital importance for the behaviour in service is appreciably lower again. It reaches about 7 % and falls as low as 4 % when the proportion of shunting work in the total work done by the steam locomotive increases.

Electric traction and Diesel traction do not show this very marked reduction in annual output compared with the optimum value of over-all efficiency. In the case of electric traction, the over-all efficiency is about 25 %. The annual output amounts to about 20 %. (If hydraulic power is used to supply the current, the annual output may even reach as high as 50 %).

In the case of the Diesel locomotive with hydraulic transmission, the total efficiency is about 31 %. The annual output is about 25 to 28 %.

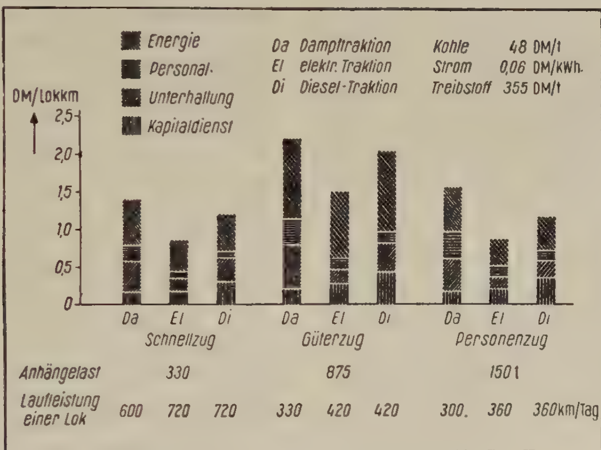

Fig. 2. — Traction costs per locomotive/km for steam, electric and Diesel traction.

N. B. — Unterhaltung = maintenance. — Kapitaldienst = remuneration of capital. — Dampftraktion = steam traction. — Elektr. Traktion = electric traction. — Diesel-Traktion = Diesel traction. — Kohle = coal. — Strom = electric current. — Treibstoff = liquid fuel. — Schnellzug = express. — Güterzug = freight train. — Personenzug = stopping train. — Anhängelast = load hauled. — Laufleistung einer Lok = mileage of a locomotive.

In this connection the steam locomotive has another very unfavourable characteristic. All railway working is characterised by a constant variation in the load on the engines, from full load to running light and to prolonged standing times, as well as to part loads. At part load, the total efficiency of the steam locomotive falls off very considerably. During the inevitable stops, the fire must still be kept up. In the same way, boiler losses by radiation continue during stops. This results in an appreciable additional consumption of coal. There is also a further consumption of power when cleaning out and relighting the fire, during the light running involved in fuelling up with coal and water, as well as to the additional radiation from the boiler and the low temperature of the feed water during winter.

This accumulation of additional losses does not exist with the electric or the Diesel locomotive. In addition, they behave better under part loads. But their chief advantage lies in the fact that with both these methods of traction there is no consumption of power while they are at a stop.

The power consumption is also unfavourably affected in the case of steam locomotives by the high weight of the locomotive itself. As only the load hauled represents the useful load, the different weights of the locomotives used for the transport which also involve the consumption of power must be included in the comparative calculations. The specific weight amounts in the case of a steam locomotive with its tender and coal and water to about 75 kg/HP. On the modern Diesel locomotives, a specific weight of 35 kg/HP has been obtained. At the top comes the electric locomotive with a specific weight of a mere 19 kg/HP. This value reflects the extraordinary simplicity of construction of the electric locomotive which does not require any conversion of the crude power on the unit, and unlike the steam locomotive and the Diesel locomotive, is not a running power station.

Result of the comparison of the traction costs.

The height of the rectangles in figure 2 shows that for the three cases under consideration — express, freight, stopping train — the costs are at their maximum in the case of the steam locomotive and at their minimum in the case of the electric locomotive. In percentages of the cost with steam traction, the cost of electric traction is about 60 to 70 % and that of Diesel traction about 75 to 90 %.

The most striking fact that emerges from this comparative study is the considerable economic superiority of electric traction. Substituting electric traction for steam traction makes it possible to save about one third of the traction costs. In these results, the following circumstance must however be taken into account : In our observations on the top place occupied by electric traction amongst possible methods of traction we remarked upon the influence of the utilisation of the fixed electrical installations (power stations, transport lines, substations, contact lines) on the profitability of electrical operation as a whole. This influence is not shown as yet in the results of the comparative study.

We stressed in particular that all the costs relating to the fixed installations for supplying power were included in the cost of power for electric traction. It follows that this factor of the costs must vary in the case of electric traction when for a given capital cost of the fixed installations, the degree of user of these installations varies. This is the case when the density of the traffic shows different values.

In reality the cost of 0.06 D. M./kWh taken as the basis for the calculations corresponds to a given value for the load on the line used for the comparison, or, which amounts to the same thing, to a given value for the specific consumption of power, which is 600 000 kWh per km per annum. If the annual consumption of current is lower, the percentage of costs for the fixed installations increases the price of the kWh used for comparison. Inversely, with an annual consumption of current of more than 600 000 kWh/km-an, the cost per kWh will be lower. This

means that the power costs, and consequently the total traction costs will be higher or lower according to whether the annual consumption of power in the case of electric traction is above or below the value of 600 000 kWh per km per annum taken as the basis for these calculations.

The economic field of application of electric traction.

If the cost per kWh has a different value from the 0.06 D. M. adopted in the comparison, the result of the comparison with the other methods of traction will automatically be modified. What should be particularly noted is that if the cost per kWh increases because the fixed installations for supplying the power are poorly used, the economic advantage of electric traction over the other methods of traction is reduced. In general, it is estimated that for a consumption of the order of 200 000 kWh per km per annum costs for electric and steam traction will be about equal. The electrification of a line operated with steam traction is therefore of no interest as a rule until the values are more than 200 000 kWh per km per annum. When it is remembered that the average consumption of current with electric traction is 25 Wh/TKBR, this value of 200 000 kWh per km per annum corresponds to a traffic of 22 000 gross t per day. Between electric traction and Diesel traction, equality of costs naturally occurs at a rather higher value. Here we can take it, according to circumstances as about 250 000 kWh per km per annum, which corresponds to a transport of some 27 500 gross t per day.

It goes without saying that none of the figures quoted are exact values; they simply show the approximate places of the economic field of application of electric traction as a function of the traffic on the line, compared with the other two methods of traction, for which as we have seen, there is no relation between the cost and the load on the line.

The economic fields of application of the different methods of traction naturally depend to a large extent on the cost of the crude power. If the ratios between the cost of coal, oil or current differ from those given in the comparative calculations, the results of the comparison will necessarily vary as well, according to the proportion of the cost of power in the total traction costs. This is why the economic advantages and disadvantages of the three methods of traction are far from being the same in all countries. The profitability of one or the other is to a large extent conditioned — apart from local operating conditions — by the actual costs of crude power.

Special economic advantages of electric traction.

In the comparison between the traction costs, we have taken for basis an operating programme which can be assured by a steam locomotive. This does not make it possible to take into account, especially in the case of the electric locomotive, certain qualities which make it possible to increase the efficiency of railway operating. These operating advantages also affect to a considerable degree the final profitability, but it is very difficult to give any actual figures in comparative calculations.

From the point of view of the power, electric locomotives are far superior to other types of locomotives at average and high speeds. The practically constant path of the characteristics of the tractive effort at the hourly and continuous ratings over the whole range of speeds makes it possible to haul even the heaviest loads at high speed, and more particularly to maintain speeds up gradients which cannot be attained by corresponding locomotives of the two other methods of traction. In this case the electric locomotive also benefits by its invaluable property from the railway operating point of view of being able to support considerable overloads. Powers considerably above the power at the hourly rating are admissible, their value being a function of the length

of time during which they last. We should also add another advantage of the electric locomotive : its low specific weight — 19 kg/HP compared with 75 kg/HP for the steam locomotive, and 35 kg/HP for the Diesel locomotive — which makes it possible to use economically locomotives with a much higher power rating than with other types of locomotives. In this way it is possible to improve considerably the user of the lines on those lines where there is very heavy traffic. The different sections of track and the stations are quickly cleared. It is also possible to deal with a large volume of traffic in a single train.

Even more important, it is possible with electric traction to level out the differences of speed between the different categories of trains — express, stopping and freight. The whole of the traffic thus flows more easily, seeing that the different categories of train interfere less with each other.

These very valuable advantages for railway working are obtained with electric traction without any ill effects upon the economic output. To quote an example, it would also be possible to avoid the reduction in speed when climbing up gradients and to increase the acceleration on starting with steam traction. But to do so it would be necessary either to reduce the load hauled or to make use of 2 or 3 locomotives to haul the train. Both of these methods would be extremely anti-economical, as when running on the level at the usual speed, the power of the locomotives used and their high weight, as well as the increase in staff, would be poorly used compared with the useful load being transported.

This shows the great advantage there is with electric traction in having the considerable fluctuations in load which are typical of railway operating taken away from the sphere of the conversion of power « heat into mechanical working » which is very sensitive to such fluctuations (2). With steam traction this conversion takes place upon the motor unit itself, whereas with electric traction it takes place at the power station which receives all the demands for power from the different motor units. The amalgamation of all these demands for power assures the power station of excellent compensation in the total power requirements. The power available at the power station for the different motor units far

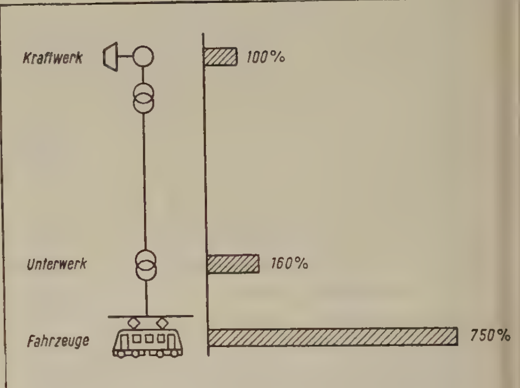

Fig. 3. — Installed power for certain important electric lines. Conditions existing in Germany.

N. B. — Kraftwerk = power station. — Unterwerk = substation. — Fahrzeuge = vehicles.

and away exceeds the actual demand in practice. On the motor units themselves, the traction motors where the conversion of electric power into mechanical work takes place can easily follow the variation in the load. The values of the power rating of the electric motors, in the substations, and at the power station (fig. 3) show very clearly how the demand for power decreases by compensation between the motor units and the power station.

(2) BRILL : « Energiewirtschaft und Zugförderung » (The use of power and traction) in « Die Deutsche Bundesbahn und ihre Industrie » (The D. B. and its industry), by the D. B. Press Information Service. Carl Röhrig, Publisher, pp. 23-24.

Use of rail motor coaches.

Whatever the advantages to the railway of the concentration of transport services, the competition from road transport has obliged the railways to give up this form of working in the case of *passenger services* and spread out the services more equally by using an increased number of small units. This result can be obtained by the use of rail motor coaches. Electric and Diesel traction both have the advantage of making it possible to use, besides the locomotives, small self-contained units. Steam rail motor coaches, on the other hand, have nowhere imposed themselves. When a rail motor coach service, seems advisable, it is therefore always necessary to give up steam traction and adopt one of the other two traction methods.

The electrification of the railways in Germany.

In Western Germany, the electrified railway system after the war extended to some 1 500 km (930 miles). Thanks to the extensions which were energetically proceeded with in the immediate post-war years, the extent of the electrified system is today some 2 000 km (1 250 miles) or in round figures about 6.5 % of the total railway system of the Deutsche Bundesbahn. According to a programme prepared by the Bundesbahn, the electrified system in a few years should extend to at least 6 000 km (3 720 miles) [3] i.e. about 20 % of the whole of the system. These electrified lines will then deal with the greater part of the most important traffic of the German Federal Railways. On the lines that have been electrified so far, the average annual consumption of current per km of line amounts to some 400 000 kWh. On the system covered by the electrification programme, the average annual consumption will reach as much as 700 000 to 800 000 kWh/km. On lines with such a high load, the economic usefulness of electrification cannot be disputed. Under such conditions, electrification is truly a proper rationalisation method, to which an Administration like the D. B. is bound to commit itself in order to reduce its present considerable deficit.

As the electrification programme of the D. B. is carried out, the profitability of electric traction will increase more and more. At the present time, the daily mileage of the electric power units are not much higher than those of the steam locomotives. But the long lines which will be obtained when the Ruhr is linked up with the south of the country will make it possible to profit by the practically limited availability of electric units and multiply their present daily mileage several times over, which will make it possible to reduce the number of units required.

To the consideration of the increase in the economic output there is another equally important factor to be added : the Rhine-Ruhr lines have already reached their full limit of capacity with steam traction. The absolutely essential increase in the output of these lines can only be obtained by electrification unless a third or fourth track is to be added.

From the point of view of power, the electrification will enable the DB to make some very valuable savings in high quality coal. The coal required will be only 50 to 60 % of that used on the steam locomotives. In addition, to fire the large fixed power station boilers it is possible to use less high grade coal or lignite.

The capital required for this electrification programme cannot, it is true, be supplied by the Deutsche Bundesbahn alone. They must have resort to the « Länder » to obtain credit. But the DB is assured of an appreciable financial

(3) Klüsche : « Die Entwicklung des elektrischen Zugbetriebes der D. B. nach dem zweiten Weltkriege » (The development of electric traction on the D. B. after the second world war) in « Die Bundesbahn », 1954, No. 9-10, pp. 365-373.

profit from this electrification, even taking into account the interest and sinking fund charges on the borrowed capital.

The capital required for the electrification of railways varies, according to the load on the line, between 50 to 100 million D. M. per 100 km of double track. In the case of the future electrifications of the DB, on the basis of present costs, they will amount to 80-90 million D. M.

The important contracts which result from railway electrifications do not profit the electrical industry alone. Only 38 % of the total orders go to electricity firms. A great number of other industrial and manufacturing firms are closely concerned and will be busy for a long time with these contracts. In addition about 80 % of the total costs are labour costs.

The electrification of railways in other countries.

The diversity of conditions obtaining in other countries may, as we have already said, lead to completely different results in estimating the economic interest of different methods of traction. We will stress a little here as an example of different conditions, on the working of railways in the United States because the predominant tendencies in that country have often led to false conclusions regarding our own operating conditions in Germany. Everyone knows that the Americans have to a large extent given up steam traction in favour of Diesel traction. Electrification, which is not very widespread, has not made any progress in the United States in recent years. The explanation of this divergence of trends on the American railways can be very simply explained by the great differences in the amount of traffic. The lines in the United States are very long, but the traffic density is relatively very low. There are only a few trains a day. It is quite otherwise in countries like Western Germany. We have relatively short lines with a very heavy traffic. The economic field of Diesel traction is further modified by the fact that in the United States there is not such heavy taxation on oil as in Germany and consequently it costs relatively less. It is therefore perfectly logical for Diesel traction to be adopted in the United States.

Systems used with electric traction.

Another question on which opinions are very divided concerns electric traction alone. This is the question of the system of current that is most suitable. Three systems have been used for long distance traffic : the 3 000 V D.C. system, single phase $16\,^{2}/_{3}$ Hz, and recently single phase 50 Hz. From the technical point of view, these three systems all meet all the necessary conditions. From the economic point of view, one or other of them has certain advantages according to given conditions. But the differences in traction costs given in the comparative calculations are often very exaggerated. The actual differences are so small that in comparing steam and electric traction, it can be admitted that the traction costs for the three systems are practically identical.

When there is a considerable load on railway lines, the question of electrification in itself must be carefully studied, and if the economic conditions are fulfilled, electric traction must be insisted upon. The choice of the best system of current is only a secondary question. *Discussions on the systems of current should never be allowed to hold up an electrification programme that has been decided upon in principle.*

Future modifications in structure as regards traction.

In the present position of traction in the world, Diesel locomotives already occupy the second place with 11.4 %. Steam locomotives still represent 84.2 % of the total, and electric locomotives 4.4 %. There is no doubt that the number of steam locomotives will continue to decline. According to local conditions, and in particularly according to the load on the line, steam locomotives will be

replaced by Diesel or electric locomotives. When deciding what method of traction is to take the place of steam traction, considerations of power economy play an important part. Countries without coal or oil resources but with much hydraulic power (Switzerland for example) will even electrify lines with very little traffic, seeing that electric traction is the only method of working which makes it possible to use hydraulic power for hauling trains.

In many countries — and amongst others Germany — besides electrification there will be a changeover to Diesel traction. Diesel engines can be used with advantage on lines with little traffic and in shunting services where electrification is not profitable owing to the cost of the fixed installations. From the economic point of view, introducing small railcars (Diesel rail buses) on secondary or local lines has given particularly good results. In this field, the only possible competitor against the Diesel is the battery railcar. For such services, the steam locomotive is particularly unsuitable, because it is not at all economic on services with only a part load and with long stops.

From the operating point of view, electric and Diesel tractions can both be used side by side without difficulty. It is already recognised today in many circles that the *correct solution to this problem is the extension of electric traction and Diesel traction.*

Although all the arguments lead to limiting steam traction as much as possible in the interest of power economy, as well as for operating considerations, the changeover is all the same an operation which can only take place by degrees over a long period of many decades. Financial considerations make it impossible to scrap prematurely thousands of steam locomotives in perfectly good working order.

It is not possible for us to predict at the present time with any certainty what modifications may take place as regards the general economy of power whilst the structure of the railway is gradually undergoing this modification. Certain indications lead us to think that the price of coal will increase compared with that of gas-oil. The substitution of Diesel traction for steam traction will be economically favoured thereby. But at the same time the field of economic application of electric traction compared with steam traction will be altered to the profit of electric traction, as it is a fact proved by experience that the cost of electric current does not increase in the same proportions as that of coal.

Neither do we know at the present time what importance atomic power is going to have in the total production of power. It seems however probable from our present knowledge that should atomic power be used for traction, the conversion into mechanical power is likely to take place in fixed power houses. Without doubt it is technically possible to build atomic locomotives. But owing to their very high weight, the ratio between the dead weight and the useful load would be extremely poor, so that the use of atomic locomotives would be anti-economic. It would therefore appear more reasonable to use fixed atomic power plants and to make use of electric power to feed the vehicles. Under these conditions, atomic power working would be purely and simply another form of electric traction, and would not require any modifications in the technique or organisation of railway operating.

In so far as we can foresee the future at the present time, it can therefore be expected that in all those countries which have adopted electric traction, this will retain, together with all the advantages in which the users of the railway are interested, all the internal advantages of profitability which it brings to railway operating.

[625 .142]

Railway tracks on concrete slabs.

A permanent way for high-speed traffic,

by Oskar EMMERICH, Diplom-Engineer, Karlsruhe.

(*Eisenbahntechnische Rundschau*, No. 10, October 1955.)

Railway track on ballast.

Since the beginning of railways the ballast bed with transverse sleepers is the only type of permanent way which has been found satisfactory in practice. This fact is confirmed by the manifold, eventually unsuccessful tyres tried out in the early days of railway construction, by the half-hearted trials with isolated elastic supports carried out about 1930 [1], and by the tests and discussions concerning railway tracks which took place before and during the war. The drawbacks associated with ballast bedding are therefore accepted as something inevitable, in spite of their unfavourable effect on the heavy cost of permanent way maintenance on the one hand, and on the maximum speed of the trains on the other hand.

Drawbacks of ballast bedding.

Ballast cannot be drained on its surface but only at its base, i.e. at the crown of the foundation. The consequent softening of the load bearing foundation has an all the more undesirable effect on the position of the track as the ballast, being an amorphous heap, is not a structural entity possessing a moment of inertia of its own, sò that it is unable to absorb, stresses and thus to support and compensate the locally different reductions in the bearing capacity of the foundation, caused by the softening process. The resulting displacements of the track in the vertical and horizontal direction must be absorbed by the running rails. But as the rail must always be a comparatively low structural element, which could not be made much stronger without heavy cost and other detrimental consequences, its moment of inertia is limited. It is therefore only to a limited extent, and within a small zone, that the rail is able to compensate the irregularities of the foundation. Even if, in order to reduce the cost of permanent way maintenance, one wished to use rails with considerably increased moment of inertia, without regard to the cost of the rail, the resulting hard and unelastic running surface would not be able to absorb harmlessly, in the form of deformation energy, the kinetic energies resulting from the unavoidable irregularities of the vehicles and their loading. Increased vehicle maintenance costs and unpleasantly hard riding would be the inevitable consequences.

Within the scope of the present study, it is essential to make it clear that the ballast possesses no elasticity in the sence in which this conception is used in the science of the strength of materials. If the ballast, when new, slightly yields under the load, this is not an elastic

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(1) A. WIRTH, « Der Oberbau der grossen Geschwindigkeiten und grossen Achsdrücke. Das Gleis auf Federn und festen Stützen ». (« Permanent way for high speeds and heavy axle loads. Track supported by springs and fixed supports »). *Organ für die Fortschritte des Eisenbahnwesens,* Vol. 82 (1927), pp. 177 to 185 and 193 to 205.

A. BLOSS, « Der Ringfeder-Schienenpuffer » (« Spring washer type rail cushioning ») *Organ für die Fortschritte des Eisenbanwesens* », Vol. 94 (1939), pp. 315 to 320.

deformation but a plastic, i.e. permanent deformation. For, the individual stones of the ballast cannot be elastically compressed by the loads encountered. Apart from the depression of the ballast into the foundation and the elastic compression of the sleepers and the small poplar plates, the yielding of the rail supports under the load can only be due to the displacement and abrasion of protuding edges and corners of individual ballast stones, i.e. due to wear and abrasion phenomena affecting the correct position of the track. These phenomena are further promoted by the fact that the framework of the track which is subjected to high-frequency vibrations due to the rolling friction of a passing train, has the same effect on the ballast as a vibrator has on vibrated concrete. With ballast-supported track, the continuous change in the track position under the impact of passing trains, calling for continuous maintenance work, is therefore inevitable.

The ballast-supported track has the further disadvantage that it cannot be cleaned by any simple method. This disadvantage is particularly pronounced with urban railways and with tracks in stations, goods yards, transhipment depots, level crossings and similar places. High cost of labour for the laborious collection of waste by hand and unhygienic stirring up of dust and dirt by every gust of wind are the consequences. Moreover, this sump of dust and dirt favours the growth of weeds which must, in turn, be kept down at further expense.

Other disadvantages of the ballast-supported track are the comparatively great depth and heavy weight of the ballast. The great depth is detrimental in tunnels where correspondingly greater excavation work is required, and on bridges where the height is often restricted so that the saving of the extra height required for the ballast would be higly welcome. Moreover, the weight of the ballast increases the deadweight to be carried by the bridges, and hence their construction cost.

Maintenance cost and maximum running speed.

The high maintenance cost inevitably associated with ballast-supported track is significant not only because of its economic effect but also because it practically governs the maximum running speed permissible. This is because the tolerances for the deviations of the track from its correct position are a function of the maintenance cost which can, of course, not be increased at will. If it is therefore possible to reduce the maintenance cost by adopting a different type of permanent way, this will, in practice, pave the way for higher maximum speeds.

Track on concrete slabs.

These drawbacks of the ballast-supported track, resulting in increased maintenance costs, are avoided with the rubber-elastic type of rail support on concrete slabs as described below. With this type of permanent way, water is drained from the surface of the concrete slabs and thus kept away from the foundations. Besides, the concrete slab has an adequate moment of inertia not only in the transverse direction but also in the longitudinal direction so that it can compensate the irregularities of the underground. In addition, there is the effect of the rubber pads which serve as rail supports. As will be seen later, the elastic compression of these rubber blocks can be so chosen that the concentrated wheel loads are uniformly distributed over the different supporting points, and the reactions of the rails are reduced. These circumstances justify the assumption that, with concrete-supported track, the correct position of the track, involving minimum wear on vehicles and track, can be ensured for a longer time than with ballast-supported track.

The concrete slabs.

Figure 1 shows the design of a track supported by concrete slabs. To avoid

cracks due to flexural tensile stresses, the concrete slabs, which are about 20 cm ($7\,^7/_8''$) thick, are prestressed in the longitudinal and transverse direction. When preparing the concrete, care must be taken to obtain a concrete of high density. The concrete slab rests on an elastic foundation and thus constitutes a stress-analytical problem for which no final solution has so far emerged in the technical literature [2]. The magnitude of the bending moments in the longitudinal and transverse direction of the slabs mainly depends on the soil resistance. In order to prevent the moments from becoming too great, the soil must be levelled and consolidated before the slabs are placed on it. Between slabs and foundation, it is necessary to insert an anti-friction layer so that none of the pre-stressing force is wasted by being partially diverted into the ground. It is particularly important to prevent the freezing of the foundation crown below the slab so that it is vitally necessary to keep out frost or, more easily and effectively, the water. As no water can penetrate from above through the slabs, it could only penetrate in the form of rising subsoil water, or from the sides, To meet these contingencies, it is necessary to construct the usual drainage ditches and to provide strong weather moulding at the edges of the slabs, with appropriate drainage arrangements.

Attention must also be paid to the arrangement of joints. Because of the prestressed reinforcement, the joints can be spaced at wide intervals (100 m [328′] and more). As far as the design of the joints is concerned, ample experience is available from concrete road construction. However, with a view to alterations to the track alignment which might be required in the future, it is possible to follow new methods also in this respect. Instead of using longitudinal prestressing reinforcement one may use flat presses which remain in the joints, and through which the prestressing effect is imparted on the slabs by pumping, the effect being perpetuated by filling the presses with cement grout. In this case, a smaller spacing of the joints (about 10 m) would have to be chosen. In this way, it becomes possible, in the case of track realignments, to shift the short slabs by removing the longitudinal prestressing. In that case, it would be necessary to provide, at greater intervals of several hundred metres, fixed abutments for the support of the longitudinal prestressing. On lines already in operation, the size of the slab will be governed by the track-laying facilities available. In this case, comparatively short prefabricated slabs might be used which could be handled by normal hoisting gear.

Support of the rails on the concrete slabs.

If the rails would be directly supported by the concrete slabs, the track would be almost completely rigid. In earlier discussions on this subject [3], it has been explained why such rigid support of railway tracks is technically neither correct nor desirable. Mention has also been made of test tracks on rigid concrete foundations tried out in the United States which, because of the lack of elasticity of the rail supports, were not successful in the long run. It would only be possible to forego any resilience in the rail supports if it were possible to avoid all

(2) General solutions are offered by TIMOSHENKO « Theory of Plates and Shells », and by BOROWICKA « Druckverteilung unter elastischen Platten » (Pressure distribution below elastic slabs), « *Ingenieur-Archiv* », Vol. X (1939), p. 113.

(3) O. EMMERICH, « Elastische Lagerung des Oberbaues auf Massivkonstruktionen ohne Schotterbett » (« Elastic support of the permanent way on massive structures without ballast »), *Eisenbahntechnik*, Vol. 4 (1950), pp. 154 to 157;

O. EMMERICH, « Eisenbahngleise auf Betonplatten ohne Schotterbett » (« Railway tracks on concrete slabs without ballast »), *Zeitschrift des Vereins Deutscher Ingenieure*, Vol. 95 (1953), pp. 101 to 105.

irregularities in the vehicles and their loading, and if the wheels could be made to run without play, on geometrically exact treads. As these conditions cannot be created, it is not possible to forego a certain elasticity of the track support. The small displacement created by this elasticity is required for the harmless transformation into deformation energy of the kinetic energies caused by the unavoidable irregularities. This requirement does not conflict with the trend, in modern permanent way technique, of making the track support as rigid as possible. For, with rails supported by individual timber or reinforced concrete sleepers embedded in ballast, the indispensable minimum measure of elasticity is still available. Moreover, with ballast-supported track, the necessary uniformity in the depression of the individual supports can only be obtained if the track is as rigid as possible. A soft ballast-supported track could not be maintained in the long run. With track resting on elastic rubber supports, however, the elasticity can be chosen in such a way that it represents an optimum for all relevant parts of track and vehicles taking part in the motion. On the one hand, the rigid unelastic concrete slab effectively prevents the non-uniform depression of the rail supports into the ground. The rubber pads, on the other hand, being industrial products of standard quality, ensure uniformly elastic behaviour under load. In considering this important question of the most favourable depression of the track under the impact of fast-moving vehicles, it is therefore necessary to discard conventional ideas and to make full use of the possibilities, inherent in the new arrangement, of reducing the wear on vehicles and track. In this connection, the consequences of broken rails or axles, particularly unpleasant on track designed for high-speed running, must not be overlooked.

The factor determining the most favourable degree of rail depression under the impact of the wheel loads is the reduction of the forces bearing on wheel and rail. A measure of these forces is the magnitude of the support reaction of the individual rail supports. This reaction must therefore be kept as small as possible. If the rail is regarded as a continuous beam resting on an infinite number of supports, the support reaction is a function of the depression. With standard rail S 49 and a spacing of 65 cm between the supports, the solution of the elasticity problem shows the smallest maximum support reaction to occur with a depression of the individual supports corresponding to $\Delta h = 2.5$ mm. Assuming, for the time being, the moment of inertia of the standard rail and the support spacing of conventional track, as well as a load distribution in accordance with load series P, a depression of 2.5 mm thus results in a uniform distribution of the concentrated individual loads over all supporting points so that the reaction forces become a minimum, amounting to about half the wheel load. If the rail support becomes more rigid, the proportion of load carried by the nearest support becomes greater. It is therefore a matter of sound technical reasoning to construct the permanent way in such a way that the support reactions are minimized by aiming at a uniform distribution of the wheel pressures over all the support points. With S 49 rail and a support spacing of 65 cm, this is achieved, as already explained, if the rails are allowed a sag of up to 2.5 mm under the impact of the load. It may be mentioned in passing that the support reaction also governs the magnitude of the bending moments in the concrete slabs in the direction of running and in the direction normal to it. It is therefore also for the sake of the stresses in the concrete slabs that an endeavour must be made to keep the support reactions at a minimum by aiming at a uniform distribution of the wheel pressures.

Whether the sag of 2.5 mm will also generally turn out to be the most favourable value from a technical and economic point of view cannot be taken for granted and would still have to be proved. But

it must be emphasized that the value merely depends on the rail profile and on the distance between supports. If the rail profile and the distance between supports is decreased the most favourable depression is similarly decreased. For practical reasons, one would no doubt adhere to the present rail profile, if only in the interest of permanent way economics as a whole. This being so, no economic advantage can be expected, either, from a reduction in the distance between supports because, if the rail profile remains the same, savings could only be effected in the design of the rail support. Here, however, a reduction in the size of the rail sole-plates would be balanced by a corresponding increase in their number. There is even less possibility of increasing the distances between supports, as in this case, not only the size of the sole-plates, would have to be enlarged, but also same of the rail profile.

There remains to consider, as a special case of rail support, the case of continuous support. In view of the plane track provided by the concrete slabs, this type of support must appear to be the logical sequel in the further development. On closer investigation, however, there are no further technical or economic advantages to be derived from such a measure. In this case, too, the magnitude of the support reaction is the governing factor, and its minimum can again only be attained by means of a uniform distribution of the wheel pressures. It is, however, obvious that such uniform distribution is much more difficult to obtain with continuous support than with individual support.

Design of the rubber pads.

As already explained, the dimensions of the rail pads are governed by the measure of the desired depression. This is already apparent from Hook's law :

$$\Delta h = h \frac{P}{EF} = h \times c, \text{ i.e. } \frac{\Delta h}{h} = \text{constant.}$$

With equal load P, equal modulus of elasticity E, and equal cross-sectional area F, the relation of the depression Δh and the height of the pad, h, has a given constant value. Therefore, if the pad is to have a compression of 2.5 mm under the impact of the load, it must not be made too thin as it will otherwise suffer plastic deformation or might even be torn to pieces between reinforced concrete slab and rail. In view of the complicated, not yet clarified relationships between pad thickness, rubber quality, type of pattern, etc., it must be admitted that the problem does not lend itself to accurate calculation. In determining the required thickness of the pad, it is therefore necessary to rely on tests. In order to arrive at comparable results, it is necessary first to choose a certain pad without regard to a given cross-sectional area, pattern or rubber quality. With a pad thus determined by utility considerations, it will be possible, by means of fatigue tests, to determine that pad thickness which permits the load to be repeated indefinitely without causing permanent deformation. In this connection, the test load must be at least 6 t, and must in any case be so great that a depression of 2.5 mm is obtained. On bridges where the support conditions are similar, satisfactory experience has been obtained, for many years, with pads of 10 to 20 mm thickness and an area roughly corresponding to standard ribbed plate Rpo 5. In determining the economically and technically most suitable size of pad, it will therefore be possible to depart from these well-proven types. Of importance, too, is the adoption of a suitable pattern which is indispensable because it is necessary to avoid a concentration of the deformation at the edge of the pad which might cause the crushing of the edge zones. With a suitable pattern, it is possible to ensure that the pads, when under load, are sucked on to the concrete so that there is force locking between pad and concrete on all sides. In consequence, the pad can also serve to transmit

the horizontal forces of the vehicle. A displacement of the ribbed plate on the rubber pad can best be prevented by vulcanisation. The most suitable material for the pads is caoutchouc-based rubber. How far this could be replaced by suitable plastics remains to be investigated. So far, the use of plastics for such purposes had to be ruled out because of the lack of indifference of these products against temperature changes. On the other hand, natural caoutchouc has the disadvantage that it is liable to deteriorate in the course of time. It is, however, possible with these products to obtain a useful life of 10 to 15 years. The need to replace the pads at such intervals cannot be economically decisive. It may, incidentally, be assumed that the chemical industry will still be able to produce an inexpensive non-ageing substance insentitive against temperature changes and other influences. The ultimately decisive factor in this connection is the presence of a sufficiently great demand.

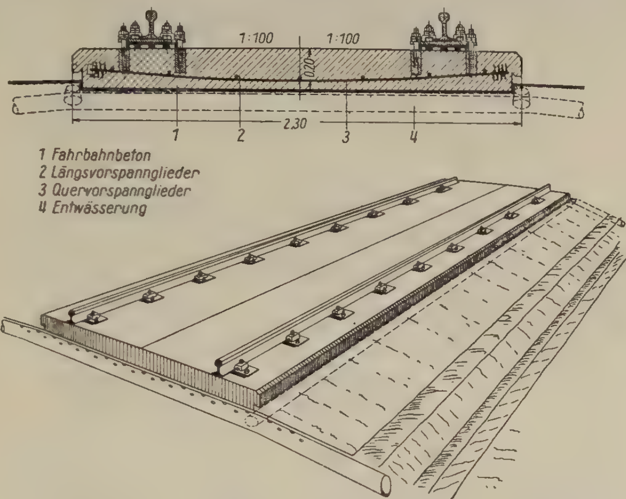

Fig. 1.

Translation of the legend:
1. Concrete slab. — 2. Longitudinal prestressing members. — 3. Transverse prestressing members. — 4. Drainage.

Tensioning and fixing the device on the concrete slab.

An important problem is the correct fixing and tensioning of the rubber-cushioned plate on the concrete slab. For this purpose, it is possible to use wooden sleepers type screws embedded is grooved dowels if their head (as in the case of

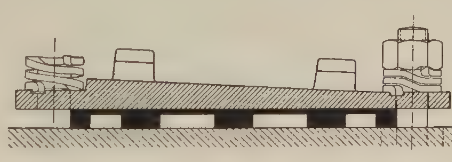

Fig. 2.

Bss 6) is provided with a thread for the application of a nut. Because of the depression of the rubber pad under the load, a suitable spring washer must be

provided between nut and ribbed plate so that the whole device does not become loose through the depression of the pads. In tensioning the elastic rail pad, care must be taken that, on the one hand, not too great a proportion of the rubber elasticity is used for this purpose whilst, on the other hand, an adequate residual tension remains when the pad is fully depressed. This question can best be clarified by comparing the force/distance diagrams of the rubber pads and the springing. Under the hydraulic press, a pad arranged as shown in figure 1 has a force/distance diagram corresponding to line 1 in figure 3. Following initially an almost straight course in the lower load range, the curve rises quickly after a load of 6 to 8 t and shows hardly any further depression at a load of 12 to 15 t. If this line 1 is compared with the force/distance diagram of the springing during the relaxation (line 3, representing the inversion of line 2), it is possible to calculate the tension still required in the spring washer after the depression of the rubber pad. If this residual tension is sufficiently reliable to prevent the slackening of the device, the primary task of the springing has been fulfiled. Accordingly, all that matters is that the spring travel is sufficiently great, or at least that it is, by an adequate margin, greater than that of the rubber pad. The greater the travel of the springing compared with that of the rubber pad the greater is the reserve available for the tensioning of the entire device when the rubber pad is depressed. There is no need to fear a blow on the screw fastening as the rubber pad relaxes, since the energy stored in the depressed rubber pad is only just sufficient to restore the original tensioning of the spring washer when the traffic load has disappeared. In this condition, however, the energy stored in the rubber pad is exhausted, and any tendency of the track to continue the upward movement could only be explained by the kinetic energy of the resilient masses and by the effect of the load on the next-but-one span. In order to intercept even this residual upward force, it is necessary to ensure that the spring travel of the tensioning device is

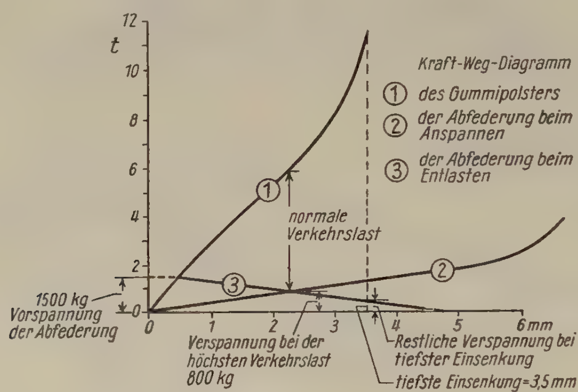

Fig. 3.

N. B. — Kraft-Weg-Diagram... = force/distance diagram : 1) of the rubber pad; 2) of the springing during tensioning; 3) of the springing during relaxation. — Vorspannung der Abfederung = pretensioning of springing. — Normale Verkehrslast = normal traffic load. = Verspannung bei der höchsten Verkehrslast = tension at maximum traffic load. — Restliche Verspannung bei tiefster Einsenkung = residual tension with maximum depression. — Tiefste Einsenkung = maximum depression.

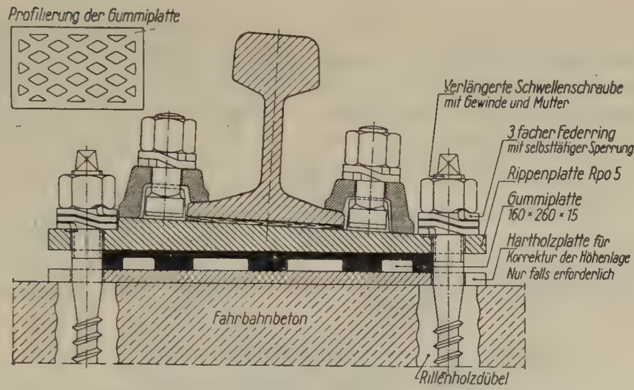

Fig. 4*a*.

N. B. — Fahrbahnbeton = concrete slab. — Rillenholzdübel = grooved wooden dowel. — Profilierung der Gummiplatte = pattern of rubber pad. — Verlängerte Schwellenschraube mit Gewinde und Mutter = extended coach screw with thread and nut. — 3-facher Federring mit selbstätiger Sperrung = self-locking triple spring washer. — Rippenplatte = ribbed plate. — Gummiplatte = rubber pad. — Hartholzplatte für Korrektur der Höhenlage (nur falls erforderlich) = hard wood plate for correct vertical level (if required).

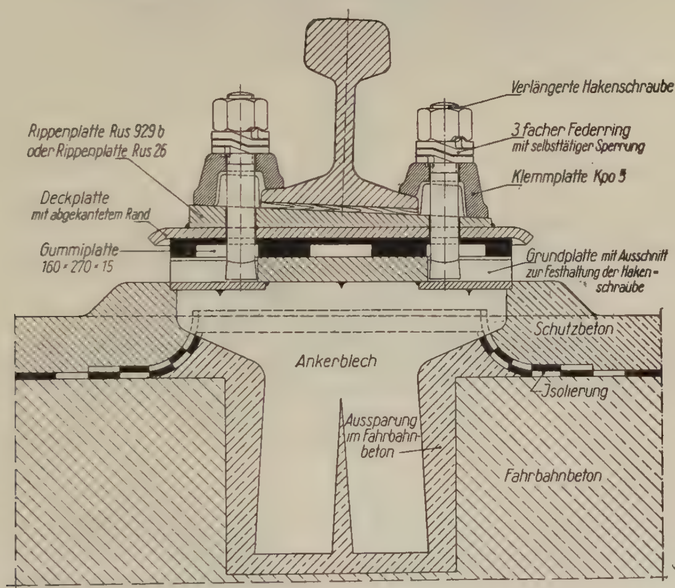

Fig. 4*b*.

N. B. — Fahrbahnbeton = concrete slab. — Aussparung im Fahrbahnbeton = recess in concrete slab. — Ankerblech = anchor sheet. — Isolierung = waterproofing. — Schutzbeton = protective concrete. — Grundplatte mit Ausschnitt zur Festhaltung der Hakenschraube = bedplate with recess for the locking of the hooked bolt. — Gummiplatte = rubber pad. — Deckplatte mit abgekantetem Rand = cover plate with bent-down edge. — Klemmplatte = clip. — Rippenplatte = ribbed plate. — 3-facher Federring mit selbstätiger Sperrung = self-locking triple spring washer. — Verlängerte Hakenschraube = extended hooked bolt.

not wholly utilized when the screws are tightened so that there is still a margin for a small upward movement.

When the screws are tightened, the spring washer must therefore be tensioned to an exactly predetermined degree. The correct setting of this tension must be ensured in a simple and reliable manner in keeping with the robust working methods in permanent way practice. For this purpose, it is suggested to use a spring washer of the type shown in figure 2. When the desired pretensioning effect has been attained, the stop of the washer comes to rest in a slot at the bottom of the nut so that the latter cannot be

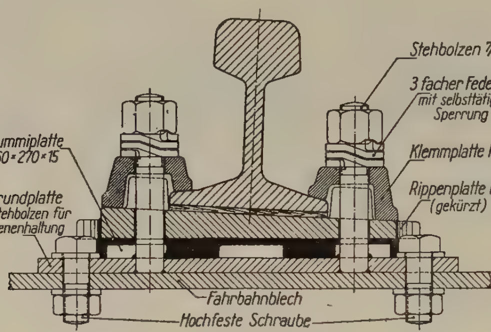

Fig. 4*c*.

N. B. — Fahrbahnblech = bridge deck plate. — Hochfeste Schraube = high-tensile bolt. — Grundplatte mit Stehbolzen für Schienenhaltung = bedplate with rail fixing stay bolts. — Rippenplatte (gekürzt) = ribbed plate (shortened). — Gummiplatte = rubber pad. — Klemmplatte = clip. — 3-facher Federring mit selbstätiger Sperrung = self-locking triple spring washer. — Stehbolzen = stay bolt.

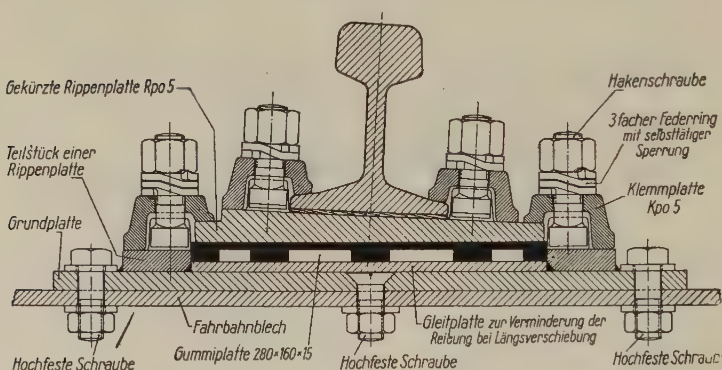

Fig. 4*d*.

N. B. — Fahrbahnblech = bridge deck plate. — Hochfeste Schraube = high-tensile bolt. — Grundplatte = bedplate. — Gleitplatte zur Verminderung der Reibung bei Längsverschiebung = sliding plate designed to reduce friction during longitudinal displacement. — Gummiplatte = rubber pad. — Teilstück einer Rippenplatte = part of a ribbed plate. — Gekürzte Rippenplatte = shortened ribbed plate. — Klemmplatte = clip. — 3-facher Federring mit selbstätiger Sperrung = self-locking triple spring washer. — Hakenschraube = hooked bolt.

tightened any further with a normal key. As the washer remains under continuous tension, the nut, on the other hand, cannot escape from the stop of the spring washer and can therefore not become loose through the vibrations under traffic.

With the proposed type of fastening, there is no direct metallic bond between rail and concrete slab. The two lines of rails are therefore adequately insulated for track circuiting purposes.

track. But displacements of this kind cannot have such a detrimental effect on the riding qualities of the track as the depression of an individual sleeper in ballast-supported track. For, what matters is not the absolute magnitude of the depressions but the gradient of such inadvertently created ramps. With concrete-supported track, a depression is therefore not only less likely to occur, because of the rigidity of the slab, but will also

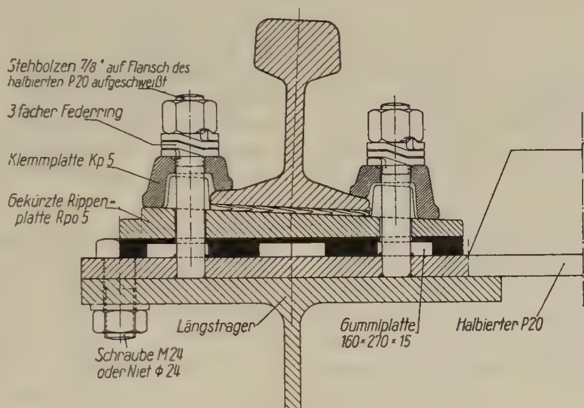

Fig 4*e*.

N. B. — Längsträger = stringer. — Schraube oder Niet = bolt or rivet. — Halbierter P 20 = half of broad-flange beam P 20. — Gummiplatte = rubber pad. — Gekürzte Rippenplatte = shortened ribbed plate. — Klemmplatte = clip. — 3-facher Federring = triple spring washer. — Stehbolzen auf Flansch des halbierten P 20 aufgeschweisst = stay bolt welded to flange of half of broad-flange beam P 20.

Horizontal and vertical alignment of concrete-supported track.

With the proposed design of track resting on concrete slabs none of the rail support points can be displaced, vertically or otherwise, in relation to the adjacent supports, as such displacements are prevented by the joint concrete foundation. This is an essential feature in preserving the correct position of the track. Because of the great rigidity of the slab, lateral displacements are practically impossible. Similarly, changes in the vertical position would not be possible except if the movement is shared by a major section of

have a much less marked effect on the riding qualities than an equal depression on ballast-supported track. Generally speaking, the frame rigidity of the track, which is a pre-requisite for a satisfactory track position and for the use of continuously welded rails, is much more reliably ensured with concrete-supported track than this can ever be the case with sleeper-supported track.

First cost of concrete-supported track.

According to reliable data, and in analogy to similar work in road construction, the concrete slab can be constructed

at a cost of D. M. 150.— per metre of track. This price includes the preparation of the foundations and the prestressing reinforcement of the slab. The rubber pads are priced at D. M. 6.— each, corresponding to D. M. 20.— per metre of track. Altogether, the construction cost per metre of track, without rails, will thus amount to D. M. 170.—. This does not take into account the savings which could no doubt be effected with the application of mechanical mass production methods.

Using the concrete-supported track on bridges.

On bridges, rubber supports for tracks have already been used in certain special cases for several years, and have not given cause to misgivings. On bridges with concrete deck, the arrangement shown in figure 1 may be adopted. Details of this arrangement are shown in figure 4*a*. If the concrete deck must be waterproofed, the waterproofing is by-passed by means of a crowbar-shaped anchor as shown in figure 4*b* so that the waterproofing itself cannot be damaged by the traffic.

In the case of steel bridges with orthotrope floor the arrangement shown in figure 4*c* is suggested. Here, the rail fastening is supported by a bedplate which is joined to the bridge floor by means of high-tensile bolts. According to tests carried out by the Steel Construction Institute of Karlsruhe Technical University, the perforation of the bridge floor required for the insertion of the bolts can be ignored for the stress analysis of the floor since, because of the high contact pressure, the flow of force bypasses the bolt hole via the bedplate. A further advantage of the device lies in the fact that it facilitates the accurate laying of the track after the bridge has been completed and handed over. Minor inaccuracies in the assembly of the bridge deck, deviations from the calculated sag, or any transition curves of the track affecting the bridge will therefore no longer cause any difficulties as they can easily be compensated by means of the bedplates. The perforation of the floor is only carried out after the track has been aligned with millimetre precision. If the rail fastening must allow movement in the longitudinal direction, an arrangement as shown in figure 4*d* might be adopted.

Figure 4*e* shows an arrangement with steel sleepers suitable for bridges with normal type stringers, and particularly suitable to compensate any differences in level at the ends of the stringers.

Future prospects.

The preceding exposition shows that the concrete slab, which is able to transmit forces in all directions, provides a better and more uniform foundation for the track than a ballast bed with individual sleepers In road construction, similar considerations concerning the maintenance and improved riding qualities of roads with heavy traffic have, long ago, led to the replacement of water-bound macadam courses by concrete slabs, which has permitted higher running speeds. In a similar way, the concrete-supported railway track will pave the way for much higher speeds on railways which, as far as the vehicles are concerned, could already have been adopted long ago. In this fact lies a possibility for a further improvement of railways which has not yet been fully exploited and which, because of the necessary safeguarding of the track, could not be rivalled by any other land-bound means of transport.

NEW BOOKS AND PUBLICATIONS.

[**385** (08 (66)]

East African Railways and Harbours. Annual Report 1955. — One brochure (7 7/8 × 9 7/8 in.) of 64 pages, with map, graphs and numerous illustrations. — 1956, Nairobi, published by the General Management of the East African Railways and Harbours (Price : 10 shillings).

The Administration of East African Railways and Harbours is responsible for railways and harbours in Kenya, Uganda and Tanganyika, the steam boat services on lakes Victoria, Kioga, Albert, Tanganyika and on the Nile, and the motor transport services in Kenya, Uganda and Tanganyika.

In general, this report by the General Manager Mr. A. F. Kirby shows that the financial results are good, with growing traffic and an increasing demand for transport.

The financial situation is dealt with to commence with. Both the harbours and railways showed an increase in receipts and their operating coefficient further improved, reaching 83 %. In spite of considerable net profits, the Administration will not be in a postion to provide the capital for the projected extensions. These relate to regions that are rapidly being developed where the question of transport is vital. The reporter studies the various possible ways of financing these projects.

In the case of the railways, the report analyses the traffic, traffic statistics and the rolling stock position. The latter has been increased by the purchase of more locomotives, amongst them Diesel line and shunting locomotives. Thanks to this increases, extensions have been possible in the case of the freight services.

The traffic of the harbours, very active, depends upon the capacity of the railway upon which it makes special demands owing to the considerable variations that occur and the lack of equilibrium between the traffic in both directions. The traffic in imports considerably exceeds the export tonnage.

In the case of the three main harbours, the operating coefficient is very favourable. In two others, special circumstances have raised it above unity.

A new railway line 209 miles long which will soon be completed in Western Uganda will link up Kampala to Kasese at the foot of the Ruwenzori mountains. In Tanganyika, another line, 72 miles long, is being constructed. This is intended to serve the Kilombero Valley, its main object being to encourage the production of sugar.

On the existing lines and in the harbours, a great deal of work is also in hand to increase the transport capacity or to obtain more economical services.

Various questions are dealt with under the heading *General Services,* in particular labour questions. The appointment of a public relations officer is one of the measures intended to advertise the possibilities of the railway.

Plans for the future are the subject of the final chapter. The investigations carried out by various organisations have reached the conclusion that East Africa will soon require a more highly developed transport system. This opinion agrees with the policy followed by the E. A. R. & H. The author gives the programme for extensions during the next few years. As regards the method of traction to be substituted for steam which will soon prove insufficient if the increase in traffic

continues at the present pace, the choice between Diesel and electric locomotives will depend upon the respective costs of fuel oil and electricity. A dam built on the Owen Falls may give the advantage to the latter solution. Finally, it is once again the question of financing this vast programme which retains the attention of the reporter.

E. M.

[**656** .25]

ASSOCIATION OF AMERICAN RAILROADS (A.A.R.), Signal Section. — **American Railway Signalling Principles and Practices.** — *Chapter III* : **Principles and Economics of Signalling.** — Revised edition May 1955. — One volume (6 × 9 in.) of 114 pages with extra figures and plates. — Published by the Signal Section of the *Association of American Railroads*, 59 East Van Buren Street, Chicago 5, Ill.

Within the general framework of signalling principles and practice as used in the United States, the « Signal » section of the Association of American Railroads has just published a new edition of Chapter III devoted to the principles and economics of signalling.

This study first of all gives a brief reminder of the indications that have to be given by the signals (stop, caution and proceed), and the principles to be respected (guarantee of correct functioning, uniformity, simplicity, possibility of extension).

An analysis is then given of the economic value of signalling, its influence on the regular running of the trains and the cost of any such irregularities such as slowing down or unexpected stops.

The methods used in the United States for calculating the traction and braking costs are given in detail, and the results summed up in a series of very clear graphs which give in HP/hours for the different types of locomotives hauling different types of trains, the loss of power when braking at various speeds.

Other graphs show directly the additional consumption of oil due to stopping in the case of trains hauled by Diesel-electric locomotives.

A calculation is then made of the cost of regaining the time lost by an unexpected stop; the results of these calculation are given in a table.

From these basic factors, after a study of the documents relating to the actual running of the trains (reports from the dispatcher, guards, and results of enquiries), it is possible to give figures for the economies which can be obtained by improving the signalling and to draw up the balance sheet for the working.

The last part of the book is devoted to the relation between economy on the one hand and the regulations and methods of signalling on the other.

This makes it possible to define other principles : the manual block, the automatic block, interlocking, C. T. C. and the protection of level crossings.

This little volume will chiefly interest operating and traction engineers.

It is to be regretted that the graphs only refer to trains of a least 2 345 t (2 125 metric tons) as they would be very valuable for making calculations in every case.

F. B.

[721]

« ENTREPRENEURS ET ENTREPRISES » (CONTRACTORS AND UNDERTAKINGS). — One volume of 250 pages (9 1/2 × 12 1/4 in.) with 275 illustrations, bound in parchment with gilt edgings. — 1956, Editions du *Moniteur des Travaux et du Bâtiment*, 32 rue Le Peletier, Paris. (Price in France, 2 000 French francs. In other countries, including postage, 2 250 French francs).

The *Moniteur des Travaux Publics et du Bâtiment* has published an important work « Entrepreneurs et Entreprises » (Contractors and Undertakings) in a luxurious edition with many illustrations, which retraces the history from their creation to the present time of forty French firms of contractors and builders who have played an important part in the equipment of France and many other countries.

The reader will learn how these firms were started, how they grew and how they overcame the difficulties that beset their path before they became famous.

Mr. Emile Roche, President of the Economic Council, has written the preface to this book which also includes — addition to the monographs on these firms — articles written by Messrs J. B. Ache, Professor at the « Conservatoire National des Arts et Métiers »; Pierre Renaud, General Commissioner of Public Works and Buildings Undertakings; René Perchet, General Manager of the Architecture at the Ministry of National Education; André Rumpler, Manager of the Highway Department at the Ministry of Public Works; Raymond Giguet, Assistant General Manager of « Electricité de France »; Robert Lévi, Manager of the Fixed Installations of the S. N. C. F.; Pierre Delattre, General Manager of the National Company of the Rhone.

This is a very vivid history of the evolution of technical skill as seen through the history of those firms and the men who successfully ran them.

* * *

May I, as a railwayman, stress in particular the judiciously illustrated analytical study by Mr. Robert Lévi. Entitled « The Contractor and the works of the Railways », this study shows very clearly how the railway and private contractors have always worked together.

If it is true that railwaymen themselves are responsible for a great deal of the technical progress achieved, private firms have often put forward ingenious solutions for the problems set them.

The exchange of ideas is mutual; a well founded collaboration always gives rise to progress and provides solutions which are not only pleasing in themselves but usually economical. Such collaboration encouraged by the reconstruction of the numerous bridges destroyed during the war, continues at the present time with the return to normal maintenance work and the work involved in the electrification of certain railway lines.

Many concrete examples are given, together with photographs, of work accomplished and to show what can be expected when all those concerned work together.

Dealing with bridges and buildings : industrial premises and hostels, Mr. LÉVI shows the results obtained to date, analysing the choice of the methods of work used and drawing attention to the new materials that are being used, such as prestressed concrete in the use of which contractors are given a more or less free hand, special steels, alloy steels and light metals.

A very extensive chapter is devoted to maintenance and renewal work on the permanent way, showing the part played by private firms in the mechanisation of such work.

The contractor has shown the same ingenuity in carrying out electrification

work at speed : special trains for concreting, for caulking the pylons, for unwinding the cables and setting up the catenary.

Work in connection with the signalling is described in detail, the accent being on « all relay » posts; in this field, exchanges of opinions between representatives of the S. N. C. F. and the contractors on a mixed signalling commission have gone very far.

In conclusion, reading this history of the post-war technique of the S. N. C. F., we get the impression that they have accomplished wonders with the assistance of the ingenuity and remarkable adaptability of French industry.

J. D.

[**625** .233]

Dipl. Ing. Eugen AUMÜLLER, Frankfort-on-Main. — **Die elektrische Beleuchtung von Eisenbahnfahrzeugen.** *(Electric lighting for railway vehicles).* — One volume (6 × 8 1/4 in.) of 184 pages with 122 figures. — 1955, Berlin/Göttingen/Heidelberg, Springer Verlag.

In this little book, which is very clearly expressed and easy to read, the author examines the present position as regards the electric lighting of railway vehicles, and studies systematically each part of the installation.

He devotes the first part of his book to the production of the necessary current.

He describes lead and alcaline batteries, giving their chemical and physical properties as well as constructional details; he shows how it is possible to design a lighting system working entirely from a battery and describes the recharging and maintenance equipment required in the shops.

He then goes on to the electric dynamo and begins by recalling the general conditions to be satisfied. Finally, after examining the various methods of driving the dynamo, he gives the electrical characteristics of dynamos and then reviews the various types of regulators used.

He ends this first part by describing the installations used for carrying out trials of electric lighting equipment.

In the second part of his book, the author deals with the use of fluorescent lighting on railway vehicles. He considers the working of the fluorescent tubes with alternating current and direct current; he also describes the installations used for converting D.C. to A.C. Finally, he gives details about the arrangement of coaches with fluorescent lighting on the D. B.

Short chapters are then devoted to the electric lighting of steam locomotives, and the lighting of electric locomotives, rail motor coaches and railcars, as well as to hot air heating installations, and air conditioning.

The book is completed by formulae and tables giving the fundamental relations and most frequently used coefficients, as well as a brief report on lighting technique, together with technical data concerning the lighting equipment and installations used in Germany.

R. S.

[**385** (09 (45)]

Dr. Ing. G. DI RAIMONDO, General Manager of the Italian State Railways. — **Uno sguardo all' Attività delle F.S. nell'anno 1955.** *(Review of the activities of the Italian State Railways during the year 1955)*. Extract from *Ingegneria Ferroviaria*, No. 1, January 1956. — One brochure (8 3/4 × 11 1/2 in.) of 44 pages with 54 figures. — 1956, Roma, *Ingegneria Ferroviaria*, Piazza Crosse Rossa.

During the year 1955, the management of the F. S. whilst continuing to efface the last remaining traces of war damage, devoted themselves to modernising the railway in order to increase its power and on the other hand endeavoured to increase productivity in the transport of both passengers and freight.

The note from the General Manager gives fairly detailed information on the various departments.

The chapter « Works and Constructions » gives details of the reconstruction of lines, renewal of the permanent way, improvements to the layout, new bridges able to carry heavier loads, and repairs to tunnels. A remarkable fact, doubling some lines is part of the programme for increasing the capacity of the system.

As regards electricity, mention must be made of the electric traction work (completion and modernisation), signalling installations, extensions to telecommunication and train lighting.

As regards traction stock, besides increases in the electric stock, Diesel traction has entered upon an active phase, partly as an experiment.

The traffic department has profited by new services, improved timetables and increased mileages. A policy of encouraging private sidings has produced very fortunate results.

On the commercial side, it is noted that output is higher than that of 1954, the average mileage having increased in the case of passenger traffic and decreased in the case of freight traffic.

The other chapters deal with stores, rationalisation, staff questions, health services, the research department.

The final data sum up in a few figures the substance and working of the undertaking. New possibilities, increased activity and a healthy financial situation are the principal characteristics of the year.

E. M.

[**313** : 656 (4)]

Annual bulletin of European transport statistics 1954. — A pamphlet (8 1/4 × 10 3/4 in.) of 88 pages with numerous tables and graphs. — 1955, Geneva, European Economic Commission (United Nations, Transport Division.) Text in English and French. (Price : 4 Swiss francs).

This document published by the European Economic Commission (United Nations, Transport Division) consists of an important series of tables, preceded by general commentaries, and illustrated by very striking graphs.

Here will be found data on the traffic (passenger and freight — by rail, water and road), on the extent of the railways, roads, and navigable waterways, as well as details about the motor stock and rolling stock of the railways, road transport and water.

All this information refers to the years 1953 and 1954, for most of the countries of Europe.

The following are some of the more salient facts which emerge from this pamphet :

— the number of railway passengers carried, per inhabitant, has varied very little;

— the international motor traffic has slightly increased;

— freight traffic has increased;

— the total length of railway lines has been reduced by 1 800 km; 1 000 km were electrified in 1954;

— the stock of steam locomotives has been reduced; the stock of wagons is constantly being reduced;

— there continues to be an extremely rapid increase in the number of motor-cycles.

The pamphlet also gives some details about the user of the different methods of transport.

F. B.

[385 .114]

Le Prix de Revient dans l'Industrie des Transports Intérieurs. Synthèse des travaux des Experts en Prix de Revient, établie par M. André BRUNET. *(Costs in the Internal Transport Industry. — Synthesis of the work of Costing Experts)*, prepared by M. André BRUNET. Two volumes (8 1/4 × 11 in.) of 308 and 252 pages respectively, with tables and graphs. — 1955, Geneva, United Nations - European Economic Commission. Committee of Internal Transport.

In countries where the transport services are very highly developed and the different methods are in competition against each other, a competition the cost of which is in the end borne by the community, government organisations and the heads of the transport industry are showing their well-justified preoccupation with both the immediate future and the long-term policy. (See in Europe : « The Problem of the Financial Situation of the Railways » published by UIC at the request of CEMT and, in the United States of America, the report made in 1955 by the Ministerial Committee set up by President Eisenhower.)

The synthesis of the work of the costing experts of the Internal Transport Committee of the CEE, a very detailed document, of wide scientific scope, prepared by Mr. André BRUNET, Chairman of the International Working Group which has been working on this question at Geneva since 1949, will therefore receive the attention not only of specialists in such questions on the Railway Administrations, but also of the university and scientific circles who are interested in the principles of the transport question, whether by rail, road or inland waterways, and their joint or comparative management.

The very clear evolution in opinions concerning the tariff bases, especially on the railway, tends to separate them from the doctrines which formerly held sway (value, distance) and approach them more nearly to the cost [1].

Moreover, the distribution of the traffic amongst the different methods of transport, the intention of making as far as possible the different kinds of transport work under the same financial conditions, and the preparation of tariffs which do not upset the co-ordination measures taken, are all reasons for studying the cost, in spite of the complexity of the cases and at times the vagueness of the data, together with the technical, commercial and legal particularities of the undertakings.

The « Synthesis » shows that in spite of a long debate about the problems of

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[1] According to one idea expressed, this may lead for example to different tariffs for small and main lines.

cost to be taken into consideration in the tariff studies, the experts were not able to agree amongst themselves in the end, owing to the structural differences between the different methods of transport, and they came to the conclusion that it was not possible to adopt standard ideas in order to assess the costs upon which the tariffs should be based.

Nevertheless, in calculating the costs of each method of transport, the experts of the CEE — and we must be grateful to them — after a detailed and exhaustive analysis of all the factors, amongst them the common charges, were able to arrive at methods of calculation which — the paradox must be pointed out — were not agreed to at the international level, although it was far otherwise with the countries whose delegates participated in the work.

Thanks to the work in common carried out, investigators in this field of economics will in the future have at their disposal :

— a terminology common to the three branches of internal transport formed by the railway, the road and the inland waterways;

— very copious data and figures which the use of methods for calculating the cost, approved by the experts, especially as concerns their very thorough subdivision into different headings and the regulations for dividing up the common charges, will make it possible to collect in a standardised form, i.e. easily accessible and unseable;

— diagrams of solutions for many problems.

Without going into details here of the observations made, we must remember that the work of making comparisons was very difficult. On the one hand, the railways which are individually big organisations keep very detailed accounts, whereas the others, both road and inland waterways, are operated by numerous firms which individually are small organisations whose resources seldom enable them to keep more than very summary accounts. In the case of these latter, the experts devoted their attention above all to a theoretical method founded on data of a technical nature, namely on a method known as extra-accountancy. In passing, it should be noted that the experts considered it was better to make use of the economic amortisation of vehicles and engines (i.e. based on their probable life) rather than technical amortisation, which is the more often used, based on the number of miles run.

The method of calculation retained in the *case of the railway* originated in the work of the Costs Sub-Committee of the UIC. In spite of the extensive accountancy system of the railways, the number and diversity of the transport obviously makes it impossible to determine the individual costs. Only the general principles can be defined, and these moreover can be applied progressively to ascertain the costs corresponding to more and more categories of transport.

Without going into the distinctions that have to be made between the average general, particular, elementary, and marginal costs, and their respective advantages and drawbacks, we may mention that the experts have given methods and typical formulae for the calculations (especially for the calculation of individual costs). They did not consider it necessary to base their work upon standardisation of statistics (which has not yet been achieved) but endeavoured to find the simplest rules which could be used by all the Administrations, and prepared an accountancy plan which includes 10 classes of accounts. The correspondence of these latter with the UIC statistics was also established.

The methods employed must obviously avoid underestimating systematically certain factors, for example particular costs, by omitting certain common costs. Checks were therefore provided, in particular that known as « linking-up ».

P. SCH.

[**625** .144 .2]

LAMALLE (Ulysse), Ingénieur civil des Mines A. I. Lg., Directeur Général honoraire de la Société Nationale des Chemins de fer belges, Professeur émérite des Cours d'Exploitation des chemins de fer de l'Université de Louvain. **Cours d'Exploitation des Chemins de fer.** — Tome III : **La voie.** — Fascicule II : **Pose de la voie en courbe.** 4e édition. *(Railway Operating Course.* — Volume III : *The Permanent Way.* — Part II : *Laying track on curves.)* Fourth edition. — One volume (7 7/8 × 10 1/4 in.) of 64 pages with 46 figures. — 1955, Louvain, Librairie Universitaire Ch. Uystpruyst, éditeur, rue de la Monnaie, and Paris, Dunod, éditeur, 92, rue Bonaparte. (Price : 100 Belgian francs).

When the third edition of this part of Mr. LAMALLE's book appeared in 1949, we stressed the importance of the steps to be taken when railway lines are laid on curves. The interest attached thereto is justified by the high speeds now practised, which tend to increase still further.

This new edition differs very little from the previous one. It was necessary because the former edition is now out of print, which testifies to its popularity.

We will merely stress the point which appears to us of the greatest importance, viz. the measures to be studied when it is impossible to obtain the theoretical superelevation. The reader will appreciate the developments relating to safety, comfort and the determination of the maximum admissible speed.

We might also recall the fact that the use of parabolic transitions between the straight section and the circular curve differs according to whether it is question of a new line or an existing line to be improved. The author gives instructions and numerical tables for both cases for the benefit of those carrying out the work in support of the theoretical study.

E. M.

M. WEISSENBRUCH & Co. Ltd.
Printer to the King

(Manag. Dir.: P. de Weissenbruch,
238, chaussée de Vleurgat, XL)

PRINTED IN BELGIUM

Edit. responsible : P. Ghilain